

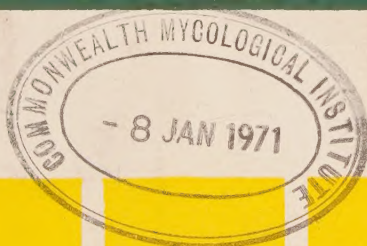
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EXPERIMENTAL ***HUSBANDRY FARMS***

EXPERIMENTAL ***HORTICULTURE STATIONS***

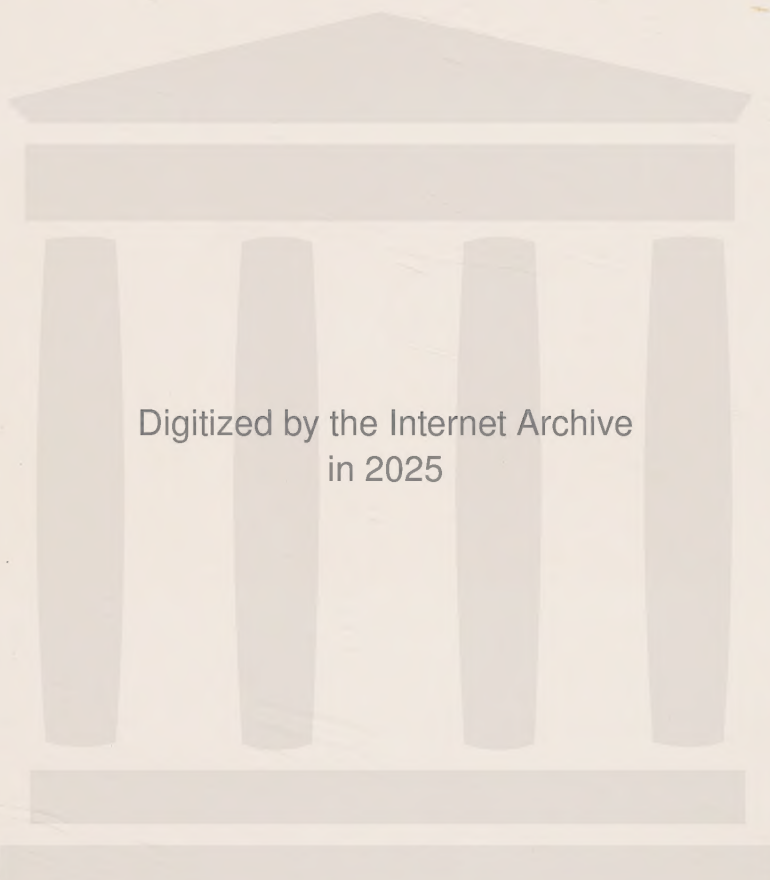
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**Experimental Husbandry Farms
and
Experimental Horticulture Stations**

ELEVENTH PROGRESS REPORT

LONDON
HER MAJESTY'S STATIONERY OFFICE

1970

First published 1970

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EXPERIMENTAL HUSBANDRY FARMS AND HORTICULTURE STATIONS.

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Introduction

This is the eleventh Progress Report on experimental work at the N.A.A.S. Experimental Husbandry Farms and Horticulture Stations.

The Report does not attempt to review the whole field of investigations in progress in any one year but presents a selection of topics of particular interest, either because they are new to the experimental programme or because they have reached a stage where conclusions of practical importance can be reported.

For a fuller account of experiments being undertaken, other publications are available. Each centre prepares an Annual Report written mainly for the farmer and horticulturist, which can be obtained from the Director concerned (address on pp. 136-138). In addition, at the conclusion of most experiments the results are reported in Experimental Husbandry and Experimental Horticulture or other scientific or technical journals.

Decimal Currency

The Sterling amounts given in this book may be converted to the exact equivalents in decimal currency by use of the following table:

1d = $\frac{5}{12}$ p (£0.00416̇)	5d = $2\frac{1}{12}$ p (£0.02083̇)	9d = $3\frac{3}{4}$ p (£0.0375)
2d = $\frac{5}{6}$ p (£0.0083̇)	6d = $2\frac{1}{2}$ p (£0.025)	10d = $4\frac{1}{6}$ p (£0.0416̇)
3d = $1\frac{1}{4}$ p (£0.0125)	7d = $2\frac{11}{12}$ p (£0.02916̇)	11d = $4\frac{7}{12}$ p (£0.04583̇)
4d = $1\frac{2}{3}$ p (£0.016̇)	8d = $3\frac{1}{3}$ p (£0.03̇)	1s = 5p (£0.05)

New Developments

LESSONS FROM A LARGE DAIRY HERD

A. L. Francis, *Bridget's Experimental Husbandry Farm*

Many people who own a large number of cows have them organized into several discreet units each of which is small enough to be managed by one man. This article is concerned with herds in which a large number of cows are run as a single unit though there may be sub-division into flexible groups within that unit for easier organization. The herd at Bridget's E.H.F. in Hampshire is of this type.

The system and organization chosen for a large herd must suit the management and men who will use it yet be sufficiently flexible for later modifications. The original concept and planning at Bridget's has proved successful, though from the outset the best advice was sought and use made of critical path analysis. The dairy parlour has now been in continuous use for two and a half years, the feed machinery and half the housing are in their third winter, and the remaining housing in its second winter. One point highlighted in the early years at Bridget's has been the necessity to provide sufficient animals to make full use of all facilities as soon as these become available.

AN EASIER JOB

The cowman is even more of a key figure in the large herd than in the small for he influences more cows, and the major challenge to management is to devise a system which maintains his interest and morale. The elimination of most manual labour by moving bulk materials, whether food or milk, by machinery, and the introduction of a five day week are two of the benefits to the staff of a large herd, and the latter is much easier in a layout planned so that two men can milk, feed, house and clean 250 cows. At Bridget's four successive days are the most any dairyman now works without a break of at least twenty four hours; thus the farm worker has begun to achieve leisure comparable to that of his urban counterpart.

The buildings at Bridget's are fully described elsewhere and an article on them was published in the Bridget's Annual Report No. 9 for 1969, available on request from the Farm Director. The major cause of damage has been the use or misuse of machinery by men; the animals have caused little harm and materials show little sign of deterioration in the first three years. Minor troubles included damage to the slurry chopper pump, possibly from stones brought into the cubicles on the animals' feet, or scuffed out of the rammed chalk that forms the base of the cubicle beds. The other machinery has also had troubles but some of these were to be expected with prototype machinery or machinery new to this country. Sufficient electricity to run the plant was another essential part of the planning.

FEEDING THE COWS

The major problem common to all dairy farms is the organization, harvesting

and storage of sufficient winter fodder, which at Bridget's includes grass silage, hay, whole cereal silage, straw and maize silage. Knowing the total requirement an attempt to meet it can be made at each stage of conservation and the balance taken on to the next crop, but the ideal of a one or two man team working right through the summer on a succession of crops is not yet realized. The same full chop harvester with a different pick up head collects grass or cuts cereals or maize directly and loads them into forage boxes which unload into a blower at the tower silos. Tower silos were considered essential, partly because of the lower level of in-store loss, but mainly because a fully mechanized feeding system was required. Barley direct from the combine is stored in two smaller silos and concentrate is delivered in bulk direct to the dairy parlour. Adequate roads to support modern twenty-ton bulk lorries are essential with suitable facilities to handle and store their loads, but the larger herd is in a better position to specify the composition of the feed it requires and to obtain it at a competitive price.

Following experiments with individual cows and groups of animals, the herd is now fed in four groups of up to 64 cows, which is the number of cubicles in each of the four sections of the building; at present only two groups of cows are fed entirely by automatic conveyor but this will soon be extended to the other two groups. The cows are grouped according to yield and stage of lactation and fed most of their ration in the feed area of the cubicle house. Careful rationing is always desirable irrespective of the herd size but in the larger herd any mistake that is made in feeding the cows is multiplied by two or three hundred.

The layout of the feed house and preparation room should be versatile. At Bridget's it has already been modified to allow food to be taken out of the system for feeding stock elsewhere on the farm, and the original idea of feeding silage, barley and a little mineral in the cubicles has been altered to include the feeding of additional protein as well. A further small amount of balanced concentrate is fed in the milking parlour, but this too is fed at the same rate to the whole group and handled in bulk.

THE SUMMER SYSTEM

In the summer a 'two sward' system is used with all the animals grazed as a single herd in five acre paddocks. A fresh paddock is used daily on a 21 day cycle and only half the paddock is available for the first 12 hours. This will eventually give an initial grazing density of up to 100 cows per acre, though 80 is the most per acre actually used so far. To guard against hypomagnesaemia 1 lb of barley with calcined magnesite is fed at each milking, and is the only additional feed for most of the summer.

When the cows are out to grass the whole time the work around the buildings is reduced to that associated with the parlour. During the summer the cubicles can be cleaned out properly and overhauled along with the feed machinery. There is a smaller quantity of relatively dilute slurry produced compared with the winter, and it is irrigated onto the paddocks after grazing; the cows begin to eat into the small areas treated in this way about nine weeks later. Most of the paddocks are perennial ryegrass, mainly S.23 or S.321. No phosphate or potash fertilizer is used on the grazing area

but 40 units of nitrogen per acre are used in the spring and after each grazing, a total of about 300 units a year. As nitrogen recirculation has built up, the higher nitrogen levels used at first have been reduced from 400 units and are expected to level off at about 250 units per acre per year.

The paddock fences are a single strand of electrified barbed wire on posts. This has always been successful in a situation where the cows are conditioned to expect fresh grazing once or twice a day. On a thin chalk soil the paddock access roadway is 40 ft wide. It is divided into two down the centre and has been adequate in even the wettest weather since each half is used for ten days in turn, then has ten days to dry out.

THE PARLOUR

The walls of the milking parlour area have now been rendered to four feet and finished off with a polyurethane lacquer which provided the best combination of price and efficiency from among the various finishes used previously on the walls of the collecting yard. The entrance to this yard is covered by a spray boom and a film of water washes the flies off the cows in the summer, keeping these pests outside. Washing pads for the udders have been replaced by sprays, and the controls for each milking unit replaced by a more up to date version. Ventilation to the milking pit for use in the summer has yet to be installed, and this is a bigger problem than keeping it warm in winter. The yields are recorded once a week on Monday afternoon and Tuesday morning, and although various oral recording systems are available and proven elsewhere, the milkers prefer to have a third person at Bridget's to do the recording and write down the yields.

SERVICE AND HEALTH

Because Bridget's was also changing breed from Ayrshire to Friesian when the dairy unit was set up there is little relevant previous history with which to compare current performance. Service by artificial insemination from nominated proven bulls was accepted from the start as the best way to improve herd performance. To this end there is a separate small standing for ten cows in the parlour block with neck yokes. Cows can be diverted into the standing as they leave the parlour though it is easy when necessary to sort out an animal from the cubicles, and this is often the practice. The use of neck yokes without stalls was wrong since this is the only time that these animals are ever yoked by the neck unless they are on experiments and therefore off the dairy unit. With well over 200 cows or heifers now in the herd there has been no difficulty in spotting bulling animals; in the past year 82 per cent were got in calf by artificial insemination within the first three services, though 7 per cent failed to get in calf even after subsequent service by insemination or a bull. Good cattle handling facilities are available and with the staff working around the unit most of the time, and the collecting yard as an integral part of the parlour, there is probably a greater opportunity to see the animals than in the previous yard and parlour system.

The veterinary surgeon now calls regularly once a fortnight on a Tuesday, when all three men are working, and attends to any minor or routine matters

such as pregnancy diagnosis, though he still comes at other times if required. Although the ideal arrangement would be to make him fully responsible, with a suitable financial provision, for all herd health, this is so closely related to daily management that the details of such an arrangement are difficult to visualize. Mastitis has not been a problem though six chronic cases were disposed of last year from a total in the herd of 220 cows. Spray washing, paper towels and a strip cup before milking, iodophore teat dipping afterwards and prophylactic treatment when drying off are routine for the herd. Judging by yield and visual impression the cows are healthier and quieter and seem more comfortable than before in yards, and there is less bullying. The only damage so far has been trodden teats which occurred when 60 cows were left overnight in a 64 cubicle compartment without lights, and the search for a vacant cubicle in the dark was obviously difficult.

Normally the cows do not behave as one large group, for in the winter a maximum of 64 are housed in one group. In both winter and summer they leave the parlour to return to cubicles or paddock twelve at a time, and in the summer up to half make their way to the parlour before milking of their own accord. The problem of 250 cows all trying to go through a 10 ft gateway at once only arises after human interference. Identification is by freeze-brand, ammonia/peroxide dye, and the use of a metal ear tag that can be read from two or three feet, and on occasion these have been supplemented by tail bands, for example to identify cows being steamed-up in a lot of dry animals.

OTHER ASPECTS

The organic irrigation system for slurry has been reasonably successful but has limitations. It will not cope with particles bigger than half an inch across and a severe blockage can burn out the pump stator if not detected in time, while any above ground part of the system must be drained in frosty weather. Despite these qualifications it has proved a quick and easy method of applying valuable nutrients to arable ground in the winter. The material at Bridget's is applied at 30,000 gallons an acre which contains 300 units of nitrogen, 150 units of phosphate and 300 units of potash, too valuable to discard as waste.

Full automation of the feeding side of the unit is also under study but this is still in the development stage and some problems are not yet solved. These include a reliable automatic weighing system, and protection for the control mechanisms and electronics from dust when cereals are being rolled and transported in close proximity. Although the principles involved are simple the controls are too elaborate for maintenance by normal farm staff, and this is also an increasing problem with the electrical equipment of the unit.

The intention is to close the herd as soon as possible and rear heifer replacements to calve down in the autumn at about two years old when they should weigh 1,000 lb after calving. The rearing system now being practised is to leave the calf to get its dam's colostrum, and for the next three days to feed colostrum from a bucket, the material coming from any freshly calved cow. Thereafter it is changed abruptly onto once-a-day cold milk substitute until it is thirty days old. It is then fed to make about $1\frac{1}{2}$ lb

liveweight gain a day, preferably less in the winter and more in the summer. The first target is a weight of 700 lb at 15 months to give a heifer of sufficient size to be bulled.

MANAGEMENT ANXIETIES

The problems for management are also complex; usually the bigger herd is one expression of farming more intensively, which often means taking greater risks. At a lower intensity many herds have spare capacity in terms of fodder supply, grazing in a dry time and other aspects that are used as insurance but which are an expensive premium in normal times. Again, if the herd is to be fed from the farm, the cereal acreage required must also be included and preliminary figures suggest that if Bridget's has something over 300 cows with 100 followers a year being reared, livestock will require more than 600 acres altogether for grass, forage crops and barley.

For excellent reasons the unit at Bridget's was built from scratch but expansion in many other commercial herds has been based on the existing buildings and animals. The capital requirement is then smaller but the main lesson from this herd will still apply; that is to make provision for the fullest possible use of the fixed resources as soon as they are available. In the longer term it is possible that the adoption of some of the ideas used in the herd at Bridget's may become essential to the survival of smaller herds, if the reduction of manual work, and the provision of a five day week and regular leisure become pre-requisites for the recruitment of suitable men.

OTHER HERDS

One member of the staff at Bridget's is already visiting several bigger herds within a reasonable distance to see how they tackle similar problems and to exchange ideas. Most of these have over 200 cows, all use a herring-bone parlour, and the majority use two people in the milking pit, although some prefer a single milker or only bring in one man in the evening if milking three times a day. Housing for the stock varies from cows out-wintered without any cover, through simple housing to cubicles similar to those used at this farm. Feeding ranges from self-feed clamp silos to tower silos with conveyor machinery, the contents being grass or whole cereal silage. Slurry is handled in a variety of ways from pushing it into a heap for a contractor to spread once a year, to tanks and spreaders or organic irrigation systems.

All the herds intend breeding their own replacements if possible but most have supplemented this by buying in animals to boost numbers in the early stages. Health, mastitis and fertility vary for a variety of reasons but with the same overall general range as in smaller dairy herds.

There is no evidence yet, either at Bridget's or in most of the herds visited, that there is any effect upon the cows that can be ascribed specifically to herd size. If anything performance has improved, not least because the managements are more conscious of the size of the enterprise and it may receive more detailed attention than before. The reduction of manual labour has also given the stockman an easier and more relaxed approach and more time to observe and think about the herd.

ANIMAL FEEDING TRIALS IN THE N.A.A.S.

G. Alderman, *Regional Nutrition Chemist, N.A.A.S. South East Region* and
M. J. Strickland, *Boxworth Experimental Husbandry Farm.*

In order to reduce livestock feed costs, new types of food and new feeding systems are continually being studied. This evaluation is best achieved by controlled experiments in which the value of a new feed can be related directly to the output of the animal in terms of meat or milk production. The limitation of these experiments is that the results only apply to the particular feeds in the one trial. In order to apply the results to other farms it is necessary to describe the quality of the feed in accepted nutritional terms.

Over the years, a considerable number of feeding trials with sheep and cattle have been conducted at the N.A.A.S. Experimental Husbandry Farms. Many of these were to provide information on the feeding value of various types of concentrates and of roughages, particularly hay and silage. One of the main points to emerge has been the limiting effect of some of these bulky feeds on the appetite of the animal, especially with the smaller and younger stock. It is clearly of little value applying feeding standards to hays and silages until it is known how much an animal will consume. By bringing together the results of a number of similar trials however, it is now becoming possible to forecast the intake of different types of roughages with some accuracy. Having established the likely intake of a particular feed, the next most important characteristic is its nutritional quality. This will often require considerable analysis of the feeds concerned in the laboratories of the Nutrition Chemists. Certain important characteristics of the forages and conserved feeds fed to cattle and sheep are difficult to measure or predict with sufficient accuracy by chemical analysis alone. Particularly is this true for the various measures of the energy which a food will yield, whether the units used are digestibility, metabolizable energy, or net energy (Starch Equivalent).

This lack of precision in assessing the energy contribution of various feeds has meant that little progress was possible in checking the various standards in use when working out rations for livestock. This type of work, i.e., ration formulation and performance prediction, forms a substantial part of the work of the Nutrition Chemists. For equally good reasons, namely that feed inputs cannot be measured accurately and regularly on commercial farms, very few feeding trials of a critical nature are carried out on such farms by the N.A.A.S.

DIGESTIBILITY TRIALS

Five years ago several Experimental Husbandry Farms, in collaboration with their local Nutrition Chemists, were already conducting digestibility trials in order to assess the feeding value of home grown roughages as accurately as possible. At this point it was agreed to introduce a standardized form of digestibility trial using caged wether sheep, based on the method used at the Grassland Research Institute. The hays and silages fed to both

dairy cows and beef cattle in feeding trials were fed to the wethers at the same time as the animals were on the main experiment.

The sheep on these digestibility trials were fed to maintenance level only, to reduce appetite effects and depressions of digestibility which occur at higher levels of intake. Carefully taken samples of both feed and faeces were subjected to extensive chemical analysis. This was done in order to improve methods of predicting energy values of hay and silage. During the last five years over 80 hays and 60 silages have been put through digestibility trials in this way. A thorough study of the first 50 hay samples received enabled the Nutrition Chemists to revise and improve their methods of forage evaluation and this benefit is now being passed on to the farmers in routine advisory work. A similar programme of work is nearing completion for grass silage, which has proved to be a much more difficult field of investigation.

The direct results of these digestibility trials, which are approximately twice as accurate as chemical methods for predicting energy values, have been incorporated in the very full records of E.H.F. feeding trials. As well as leading to immediate and useful conclusions about each trial as it was completed, particularly in terms of actually recorded performance compared to expected performance, the accumulated data of all E.H.F. feeding trials for the past five years have recently been subjected to computer analysis.

ENERGY STANDARDS FOR RUMINANTS

This work has been undertaken by the Department of Statistics at Rothamsted Experimental Station, using the Orion computer and specially written programmes. The main objective was to compare Starch Equivalent and Metabolisable Energy as methods of assessing animals' needs for energy. To do this, data on the following items had to be included in the calculations so that the comparisons were as accurate and free from bias as possible.

- Feed inputs in dry matter terms for each feed in the trial on an individual animal basis.
- Details of chemical composition of all feeds fed.
- Details of digestibility trial results for forages.
- Liveweights of animals at weekly intervals.
- Milk yields as weekly totals.
- Milk composition figures for fat and solids not fat.

An intricate programme of calculations and corrections ultimately leads to a predicted animal performance from both the Starch Equivalent and Metabolisable Energy systems, and these are compared with the actual performance recorded on the farm during the trial.

Final print-outs for both growing and finishing beef animals and for dairy cows are now being obtained and a systematic study of the results is being undertaken by a working party of the Nutrition Chemists and research workers.

The volume of data being studied in this way is probably unique, covering as it does hundreds of animals in most of the feeding trials conducted on E.H.F.s for the past five years. It would not have been possible without the most whole-hearted co-operation between E.H.F. staffs and Nutrition Chemists, to the great advantage of both in understanding and interpreting trial results, and improving nutrition advice to farmers.

A NEW DRAINAGE EXPERIMENT

J. E. Whybrew, *Drayton Experimental Husbandry Farm*

Although some work has been done in various parts of the country, there is a singular lack of information about the economics of drainage and its effects on soil conditions.

In an attempt to rectify this deficiency, a drainage experiment has been laid down at Drayton E.H.F., on a lower lias clay soil to try and provide some information on these two important aspects. The experiment is being conducted in association with the Experimental Drainage Unit, Anstey Hall, Trumpington, Cambridge, and the West Midlands Regional N.A.A.S. Soil Science Department.

The experiment is sited on the Evesham series of the Lower Lias which has been described by the Soil Survey of England and Wales as follows.

'On Lower Lias clay with little drift. Drainage slow. Mottling and manganese concretions indicate impeded drainage from 3 in. down. Texture is clay (about 60 per cent clay fraction) and all layers are calcareous, the surface layers containing less than the lower layers. Occasional Bunter pebbles and small fragments of limestone are found.'

Preliminary work on the site showed that permeability was very low, (11 mm per 24 hours) and that the water table measured in small dip wells during the winter and spring of 1968/69 was within 4 in. of the surface for 70 per cent of a possible total of 48 weekly observations.

Three main treatments have been planned:

- a very widely spaced tile system with permeable fill to within 15 in. of the surface, the equivalent of a mole cum main tile system;
- a medium spaced system with laterals every 96 ft and permeable fill to within 15 in. of the surface, and
- an intensive system with laterals at 48 ft and no permeable fill.

On some plots either subsoiling or mole drainage will be superimposed on the tile system. In addition a further treatment will have no drainage whatsoever, except that which occurs through the natural agencies of soil pores and fissures. Each plot is just under an acre in area and is isolated from neighbouring plots to reduce the effects of lateral sub surface drainage by a polythene film inserted 3 ft. into the soil and reaching up to plough depth.

Replication of treatments is desirable in all field experimentation in order to be able to estimate the reliability of any observations recorded. In the case of an experiment such as this, with very large plots, replication in area becomes virtually impossible. However, two treatments, the intensive tile system and the 'control' plot receiving no drainage, have been duplicated to provide some estimate of the field errors involved.

Plot yields will be recorded, and observations made on soil workability whenever cultivations are carried out.

The drainage water collected from each system is conducted to the side of the field via a sealed pitch fibre pipe through an automatic flow recorder and thence into the ditch. An automatic rainfall recorder will be installed so that rate and period of drain flow can be related to the amount of rain falling over a known period of time.

In the early stages, the experiment will be cultivated and cropped as a whole although it might prove possible to subdivide if circumstances suggest that this is worth pursuing. The rotation will be the one followed on the intensive arable block of the farm, i.e., 1 yr. ley, w. wheat, w. wheat, w. beans, w. wheat, w. wheat, w. oats, w. wheat, spring barley undersown with 1 yr. ley.

NEW FARM BUILDINGS AT TRAWSCOED

J. C. Wilcox, *Trawscoed Experimental Husbandry Farm*

At some time all farms get to the stage when their buildings have become outdated and inadequate and experimental husbandry farms are no exception to this rule. Any rebuilding poses many questions for those who have to design the buildings and layout, but probably the most vexing are the ones concerning general purpose versus specialized buildings and what developments are likely to occur over the next few years. The problem of whether long life expensive buildings or cheap temporary structures should be put up also has to be resolved. On an experimental farm further concessions in building design may have to be made to provide adequate facilities for the experimental work.

Some of the existing farm buildings at Trawscoed Experimental Husbandry Farm have now reached the stage where old age and outdated design has made their replacement urgent. Some unsafe buildings have already been removed and this opportunity to replan the farmstead, as far as possible on more rational lines, has been taken. Additional accommodation for the expanding livestock numbers is incorporated in the plans and some thought has been given to flexibility to cope with possible future developments.

The programme has already got under way with the provision of a new barn in which it is planned to install machinery to mill and mix the feed for the expanded dairy and pig herds. Also due to be erected in the near future are a calf house with individual pens, and a weaner pool which will complete the buildings needed for the expansion of the pig herd to 100 sows.

A new milking parlour is of top priority and it is hoped to install a low line 12 : 12 parlour within the next twelve months. Provision of housing for young stock is to be made and it is hoped that a pole barn building can be erected by the farm staff for this purpose in the near future.

The present dairy cow housing and silo will have to be replaced over the next few years and a package deal building may be adopted for this.

It is hoped that a pole barn type building can be erected and fitted with cubicles to house the expanding beef suckler herd. This will be of similar structure to the sheep housing which has been put up over the last two years.

Various alterations will be made to the remaining old buildings to provide calving boxes and isolation boxes and a larger workshop. In the near future an additional implement shed is needed and an office block to house the staff so that an increasing experimental programme can be more closely co-ordinated with the everyday farming.

NEW FACILITIES FOR EXPERIMENTAL WORK WITH POULTRY

S. P. McClean, *Gleadthorpe Experimental Husbandry Farm*

During the 1960's, the poultry industry has witnessed considerable developments in housing for both egg and broiler production. This has resulted in the appearance of large windowless houses in which the environment, which has a major influence on the performance of the birds, can be controlled. The producers who have adopted these housing systems continue to seek the assistance of the N.A.A.S. Poultry Advisers to improve their competitive efficiency. These advisers need to have first-hand access to the results of applied experimental work, especially planned with their requirements in view. The ARC and the universities undertake the more fundamental research work, and although of extreme value, this does not fully meet the Adviser's needs, and there is a demand for a programme of applied experimental work on poultry producers' problems.

From their early years, Gleadthorpe and Great House E.H.Fs. ran fairly small scale poultry enterprises, and over the years carried out various experimental work planned in collaboration with the poultry advisers. However, in 1966 it was decided that N.A.A.S. poultry work should be concentrated on one farm. The poultry enterprise at Great House was discontinued and Gleadthorpe was chosen to be the centre where expansion should take place.

At present, there are two laying houses at Gleadthorpe E.H.Fs. a battery containing 2,200 birds and a deep litter house for 1,000 birds. In these houses, experiments are being carried out to investigate the incorporation of various levels of beans in layers rations, and the effect of pigments added to the feed on yolk colour.

During 1970 a new battery house is to be erected, in which it is intended to investigate initially certain aspects of environmental control in poultry houses. This battery house will hold 7,200 birds in eight separate compartments, each for 900 birds. Each environment to be tested will be operated in two 900 bird compartments simultaneously, so that if any of them produce unsatisfactory results it will be possible to detect these with a reasonable degree of accuracy. Smaller groups of birds would be too far removed from commercial practice to be realistic.

The first experiment will compare the effects of different temperature and ventilation treatments on laying hens. Two strains of bird and two diets will be used to see to what extent these interact with the environmental treatments. The sort of regimes to be tested are ones that can be operated in commercial battery houses with good insulation and automatically controlled fan and heater equipment. It is intended that all the environmental work at Gleadthorpe should be conducted in this practical context.

NEW GLASSHOUSES AT EFFORD

R. F. Harnett, *Efford Experimental Horticultural Station*

There has been a tremendous improvement in house design in the last 15 years made possible by the production of new materials and engineering techniques. Glass, used to protect crops for two centuries, is still however the most favoured transparent material and is likely to remain so throughout the 1970s. Clear plastic sheets offer a potential alternative but these are at the moment in the early stages of testing. Thin plastic, e.g., polyethylene, is now commonly used for advancing crops slightly out of season, but its susceptibility to damage in high wind, relatively short life and the reduction in light penetration, make it impractical to use for crops with a high heat requirement in the winter months. The prospect of being able to dispense with natural light by using artificial illumination and building rooms of an opaque material is not foreseen in the near future for anything but small intensively grown areas used for early plant propagation.

During the short days of winter when the sun is only above the horizon for about 8 hours a day, the advantage of a house designed to transmit the maximum amount of total light is of particular importance. Research work at the John Innes Institute has shown that the orientation of the house considerably influences the light transmission in winter. A few years ago the common type of structure consisted of small glass panes carried by heavy wooden glazing bars which cast large shadows onto the ground covered. The coming of alloy metal extrusions was an important step in overcoming this problem, and with the help of engineers, many with experience in other industries, glasshouse design has today reached a point which can only be improved upon by the use of thinner and stronger materials hitherto not available.

There is however, still a big difference in thinking between growers as to the best type of glasshouse to erect. Broadly the choice lies between building a structure in single spans which have a large, clear working area and a good light transmission, or a cheaper multispan structure with a poorer light transmission. Generally growers on the South Coast belt, who benefit from the good natural light in winter in that area, favour the expensive widespan, and those in the poorer light conditions and colder areas of the North prefer the cheaper multispan structure. There are various other reasons for this regional trend of thought but the answer as to the right sort of house for a particular area is by no means clear.

For this reason it was decided that various house designs should be erected at Efford. In December 1968, work started on building four $\frac{1}{4}$ -acre houses of different design and orientation. Two houses are of the single widespan type both orientated east-west as it has already been established that more light enters this type of house when sited with one side towards the sun rather than if the ends face north-south. Both houses are 180 ft long $\times$ 65 ft wide, one having a roof shape with a conventional 27 degree pitch, and the other with two pitches to each side of the roof, called a Mansard type (plate V upper). The Mansard shape is commonly seen on dwelling houses and has been applied to glasshouses because the angle of glass to the low winter sun allows a greater amount of direct light to penetrate through to the plants.

The other two structures are of the multispans type and identical design, each 100 ft long $\times$ ten 10 ft bays. In the case of the multispans structures there is no scientific evidence as to which way the houses should be orientated and therefore one is built with the ridges running east-west and the other north-south. All 4 houses are large enough to eliminate effects that the sides and ends may make and the middle will be representative of a much larger building. Some houses today cover areas of over 5 acres.

Apart from the design and orientation all other factors are aimed at being as even as possible. Ventilation, heating and CO₂ enrichment will be precisely maintained by automatic controls. The direct and total light entering the houses will be recorded by Kipps solarimeters positioned in different parts of each house. The first crop to be grown in the four houses will be tomatoes. The tomato has been chosen primarily because of its economic importance to glasshouse growers on the South Coast, also on account of its sensitivity to the amount of light it receives, its ability to grow a uniform plant from seed permitting measurement of growth performance, and the relatively easy method of assessing the crop by weighing and grading the fruit from different areas within each house.

The first crop was sown in November 1969 and will be producing fruit from March until November 1970 when the crop is pulled out in readiness for the next season. To avoid variations caused by Tomato Mosaic Virus commonly found in tomatoes, a new variety has been chosen that is resistant to the disease. Tomatoes will be grown for at least 3 seasons in the 4 houses so that performance is checked over years of varying light. For instance, the difference in total light between a bright January can be three times that of a dull one.

The results will be looked at by the economist, management experts, as well as the horticulturalist. The economist will assess the crop yield and value from each house, and having taken into account the capital outlay of the units, will be able to state which building is the most profitable for any grower's situation. The management adviser may find that more mechanization is possible in a house with a clearspan working area, making less demands on labour and easier working conditions. Many theories of economy and management have been put forward to the grower but there has never before been an area of glass of this size where such comparisons can be accurately made. This unique unit will be of immense value to the grower and research worker alike.

STUDIES ON MECHANICAL BRUSSELS SPROUT HARVESTING

P. B. Tatham, *Efford Experimental Horticulture Station*

For a number of years the experimental programme on Brussels sprouts at the Experimental Horticulture Stations has been largely directed towards the development of a single harvest system of production which would ultimately allow the fullest use of machinery at harvest time. Many problems of production remain but it is now generally true to say that it is answers to problems on the mechanical side which are now lacking. The actual stripping machines, the development of which started the ball rolling a few years ago, have by and large proved quite satisfactory. It is now the whole system of going about the job which poses the real problems, and it is at this point, probably because no one method will cover all eventualities, that the development of machinery is lagging behind. A project arranged jointly with the National Institute of Agricultural Engineering started in 1969 at Efford to look at systems of harvesting and handling. This has the unavoidably broad objective of gaining information which will eventually enable decisions to be taken by growers on the most suitable approach to adopt in any given circumstance.

What possible approaches to mechanization are there? There are perhaps three basic systems. These can be defined in principle but the variations within them are too numerous to describe here.

Maximum packhouse effort: All work except cutting the stems takes place in the central packhouse building.

Basic packhouse effort: Preparation of sprouts for market takes place in a central packhouse building, stems are cut and buttons stripped in the field.

Complete field production: Fully mechanized combine harvesting is not at present feasible.

The first system involves the use of one or more static stripping machines built into a production line with cleaning and grading equipment connected. This approach enables the maximum use of labour in warm dry conditions, in contrast to the unpleasantness of traditional field picking. Employing four men and four women for example, this layout could cope with about 30 acres a year. Using a mechanical stem cutter and loader such as the Universal Vegetable Harvester the capacity could be doubled with perhaps the addition of one extra man.

For the second system the cleaning and grading aspects of sprout preparation take place in a central packhouse using casual labour, while actual sprout stripping goes on at the field site, either by the use of a mobile or a static headland stripping unit. Only pallet boxes of sprouts come to the packing shed and the capacity of the line can be enlarged as required to receive sprouts from one or more farms. This approach therefore suits a co-operative effort very well.

The high capacity combine unit fed by a cutter elevator has not yet been perfected. Large mobile units fed with hand cut stems and equipped with fairly sophisticated cleaning and size separating equipment which can produce market samples ex-field are the nearest approach to complete field

production at present. How desirable it may prove to do the complete job in the field, which may lead to much land poaching in poor weather conditions if work can be done at all, is open to debate.

In enumerating the studies that are being undertaken by N.I.A.E. it is stressed that there is no question of attempting to establish a 'best' system; there are far too many variables for this. The aims of the individual farmer and the possible outlets for the produce must influence the farmer's choice of method. The existing resources of land, labour, machinery, buildings and capital must all also be considered in the light of the proposed capacity of the whole enterprise, whether it be an individual farmer or a group. An answer is found in each case by weighing up all these factors and it is to help with this that certain basic data need to be collected.

The most obvious need is to obtain accurate information on unit work rates. Suggested capacities are published by manufacturers for stripping machines and for ancillary equipment. Work rate assessments have been made for individual stripping machines by N.I.A.E. and in joint N.A.A.S./N.I.A.E. studies at Efford during the last few years some data on qualitative performance has also been obtained. In 1967 a comparison between machine stripping and hand stripping of single harvested stems was made. The object was to assess losses arising from the use of machines for this operation and not to compare mechanized with traditional field harvesting. Four varieties (Early Half Tall, Champion, Gravendeel and Seven Hills, transplanted and drilled) were grown for a season's continuity from September to January. The stripping machine used was that manufactured by P. J. Edmonds in which stems first have to be pre-stripped in a revolving saw hole, where small buttons and leaf petioles are removed. The stems are then pushed into a bevelled orifice to be gripped and pulled through by cage wheels so that buttons are forced off at their point of natural abscission. In control samples all buttons were removed by hand.

The results showed that some losses did occur with machine stripping but these were not as serious as might have been expected. Losses occurred only with Early Half Tall, Champion and Gravendeel and were confined to the smaller grade of sprout (under 1 in. diameter). Losses only assumed worrying proportions with Champion in October when the yield of sprouts sized $\frac{3}{4}$ –1 in. was reduced by up to 25 per cent with machine stripping. With Champion this grade represented 30 per cent of the total yield. It was noted that losses were mainly as a result of damage in the pre-stripping operation.

In 1968 a comparison was made between the Edmonds machine described above with another machine manufactured by Dokex Ltd., which removed buttons by drawing the stem butt first through a set of revolving knives. Using Champion harvested in October the results confirmed that high percentage losses could be expected in the smaller sprout grades. Under normal commercial practice the knife acting machine caused less destruction of buttons but if good sprouts were recovered from pre-stripped trash (and this is extra work) there was little difference between machines in terms of overall loss. A point in both experiments was that losses due to machine stripping were greater with stopped plants than with unstopped plants. This in no way counteracted the advantage of stopping for early season production but might be important where stopping is having little effect on yield.

With this basic knowledge now available it is information on performance of machines within a system as they are affected by the system that is now lacking. For instance, stems cut by hand may handle differently to stems cut by a cutter elevator such as the Universal Vegetable Harvester. Regrettably sprout stems do not remain free from rots all season so how much influence does the amount of rubbish cut with each stem have on subsequent stripping; is it worth cutting above the dirty part of the stem to avoid this?

Almost directly connected with this aspect is the interplay of the recommended cultural practices with subsequent machine handling. Deleafing can be a time-consuming operation and growers naturally look first at methods of speedy and yet apparently sufficient bulk leaf removal, perhaps by the use of rings. But it may be that a little more care here would result in greatly reduced cleaning requirements at the packhouse end. Season has an influence on this for when leaves begin to flag a ring deleafaer often does a ragged job and a simple knife, though slower can be more effective. Within this context some value in terms of throughput can be put on the uniformity that hybrid varieties offer.

Perhaps the most important aspect on which information is required, is that of the assessment of loss of potentially marketable sprouts. Hand picking is naturally so selective that usually only dirty sprouts fall to the ground but at every point where non-selective machinery is employed, good sprouts can be lost. Already it is obvious that levels of loss can be surprisingly high but whilst the awareness of where or why and how much loss takes place may enable refinements to be made which will reduce these levels, there will inevitably be some losses in a mechanized system that will have to be accepted. Success will depend then on the marketable yields beyond that.

The programme of work is scheduled to continue into 1970. When results are complete the Advisory Service will be more able to help growers select the most suitable method of approach. The logical extension would seem to be the computerized formula into which the requirements, facilities and limitations of the grower could be fed, and the answers in terms of size of enterprise, method of growing and harvesting system to be adopted can be read off.

PROTECTION OF CROPS AGAINST BIRD DAMAGE

B. Ebert, *Luddington Experimental Horticulture Station*

Damage done by various kinds of birds to growing crops is a continual problem in all the major horticultural areas. At Luddington damage by wood pigeons occurs at intervals throughout the year but increases towards late winter when established Brussels sprouts and spring cabbage are attacked and is severe in March and April at the setting out stage for small brassica plants. Even an attractive bird like the skylark can be a menace when in late February small flocks peck out the growing points of spring cabbage. On gooseberry and tree fruits, damage done by bullfinches to dormant and swelling buds can be severe in some winters. As these buds are not replaced by the tree in the same year and as one bird can remove buds at the rate of 30 or more per minute, a small flock of birds feeding in an orchard can cause drastic loss of yield.

At Luddington in 1969 various means to deter wood pigeons from feeding on brassica crops were tried, together with a stupefying bait for reducing their numbers. The use of polythene strips, aluminium foil, black cotton and rope cartridges, all proved to be of temporary value. A tethered hydrogen filled balloon flown at different altitudes to simulate a hovering hawk was partially effective for deterring larks and pigeons, but with an average life of three days and being of little use in strong winds, such devices had severe limitations. A licence to use tick beans coated with a 2 per cent alpha chlorolose slurry was granted in March 1969. The use of a large seed, like a tick bean, prevents birds smaller than a wood pigeon being narcotized. Rates of use were:

to protect 5–20 acres of crop 80 lb tick beans spread over 10,000 sq. yd;

to protect over 2 and up to 5 acres 40 lb beans spread over 5,000 sq. yd;

to protect under 2 acres 20 lb beans spread over 2,500 sq. yd.

Date	Recovered birds	Crop	Amount of bait used	Level of damage 0 = nil 5 = severe
20 March	1	Spring cabbage	10 lb	2
5 April	0	Early summer cabbage	10 lb	3
21 April	0	Brussels sprouts	20 lb	4
21 April– 15 May	4	Early summer cauliflower	15 lb	4
3–18 June	34	Brussels sprouts	15 lb	1
15 June– 8 July	14	Autumn cauliflower	10 lb	1

The application rate was in the order of 1 bean/sq. ft and the cost was approximately £1/acre crop protected. The table (see page 17) shows the number of wood pigeons taken at Luddington, the crops on which the bait was used and the level of damage on the crop in spite of the use of narcotics. During the period from late March to early July, no other species of wild bird was recovered.

The table shows that in the months when damage was severe (March-early May), few birds were taken. At this time although the birds freely fed on adjacent uncovered seed barley their feeding image appeared to preclude them from taking tick beans. In June and July when a range of alternative food was readily available, apart from a small amount of initial damage, the birds appeared to show preference for the beans.

A major investigation into the nature and extent of wood pigeon damage to brassicas in the Vale of Evesham is being carried out by the Ministry's Land Pests and Birds Research Department.

Also in 1969 seven materials applied to dormant fruit buds were fed to caged bullfinches in an attempt to find an effective and persistent deterrent. 15 wild birds were collected from traps in various parts of Worcestershire in December 1968. The birds were housed in 3 cages built into a 62 ft shaded Dutch light structure and some even paired, made territories and built nests the following spring. Plum and apple trees were sprayed with deterrents in the orchard and branches were cut and fed 4, 11 and 18 days after being sprayed. Branches were set out in a 4 block randomised system and were held firm in the cages by inserting the ends into straw bales. Each branch carried approximately 100 buds and nine tests were run during the course of the experiment. The feeding period on the buds was restricted to 2 hours and at all times during the tests alternative food was available in the form of normal finch seed, together with green food such as groundsel and chickweed. The number of buds going into the cages and those missing at the end of the two hour period was recorded. Under these conditions, no material was capable of completely limiting bud damage. The 'take' of buds, irrespective of treatment was always high near favourite perching sites within the cages. A mixture of flour, lime and a cellulose sticker generally had lower bud loss than any of the other treatments but this material could not be applied through a normal spraying machine. This partial lack of bud destruction appeared to be associated with the thick deposit disguising the outlines of the fruit buds. Where the deposit was thin, bud damage occurred.

Further work will involve evaluation of several formulations of the flour mixture. Principal requirements will be to obtain a non-phytotoxic material capable of commercial high volume application, to give a thick deposit which breaks up the distinct outline of the fruit bud and persists on the tree for 6-8 weeks. It is hoped to examine new formulations of the flour, lime and a cellulose sticker during 1970.

Results from Recent Experiments— Arable Crops

BREAK CROPS FOR CEREALS

Work on break crops at Experimental Husbandry Farms has followed two directions: studies of methods of growing the crops concerned, and assessment of their effects on following cereal crops.

Part I

THE HUSBANDRY OF BREAK CROPS

P. B. Harris, *Bridget's Experimental Husbandry Farm*

Break crops that can be grown and harvested with the conventional machinery used for cereals range from those like oats that have been grown on farms for many years, to comparatively new introductions like oil seed rape, and also include field beans which have returned to popularity in the last few years having once been grown on a much wider scale.

Leaving aside variety trials carried out in co-operation with the National Institute of Agricultural Botany investigational work on the husbandry of these crops at Experimental Husbandry Farms has necessarily followed the same sort of pattern. Studies of methods of growing oil seed rape and beans are comparatively recent but experiments on the cultivation of oats extend over a number of years.

OATS

Winter oats

Of the more recent work experiments at Rosemaund in Herefordshire and at Boxworth in Cambridgeshire have been concerned with the husbandry of the winter oat crop in respect of time of sowing, seed rate and level and timing of spring nitrogen applications.

At Rosemaund, the sowing dates compared were a normal one in early October and an earlier one in mid-September, using the varieties Padarn and Peniarth. In 1965 a slight increase in yield was gained by sowing earlier, but generally there was no advantage. Boxworth compared a normal time of sowing in mid-October or early November with another in December or January and a late one in February, using the variety Peniarth. Sowing in January led to reduced yields, and they dropped even more when sowing was further delayed until February.

Seed rates were investigated at Rosemaund over a number of years, at first with the variety S.172 and later with Padarn and Peniarth. The comparison made was between 84, 140 and 196 lb of seed per acre, and in most years the middle rate gave the best yield.

On the subject of spring nitrogen application to winter oats, the general conclusion at Rosemaund was that 30 units per acre was sufficient and this produced an increase in yield of over 4 cwt per acre compared to oats

grown with no applied nitrogen. Little increase occurred where higher rates were applied, and application of the nitrogen in March was found to be generally more effective than a later dressing. At Boxworth, applications of 60 units in some years gave a marked increase in yield compared with 40 units per acre: in other years however severe lodging resulted with consequent yield reductions. In 1967 when times and rates of application were compared, 40 units per acre gave the maximum yield, 6 cwt more than where no nitrogen was applied, but there was little difference between top dressing in mid-March or late April. Splitting the application between these two dates caused rather more lodging and reduced yields.

The use of chlormequat to reduce lodging in the winter oat crop was investigated at Drayton Experimental Husbandry Farm in Warwickshire when nitrogen was applied at rates of 40, 70 and 100 units an acre in 1967, and 45 and 90 units per acre in 1968. The chlormequat was applied at 1 lb of active ingredient per acre at growth stages 5 to 7 when the plant internodes were lengthening. Some increase in yield occurred on the chlormequat-treated plots at all nitrogen levels in 1967, but only at the highest level in 1968. The application of nitrogen at above 40 units per acre did not increase yields except where in 1968 chlormequat had been used.

Spring oats

Methods of establishment of spring oats were studied at High Mowthorpe Experimental Husbandry Farm in Yorkshire in 1968 on a field scale. Good results were obtained by broadcasting the seed with a spinning disc fertilizer distributor and yields were similar to those obtained by drilling in $4\frac{3}{4}$ inch rows with a 33 row drill. At the same farm in 1968, nitrogen application rates for spring oats were compared. There was little response in yield to over 40 units per acre applied to the variety Astor following a ploughed ley, and severe lodging occurred where 65 and 90 units per acre had been applied. On land previously cropped with cereals however, 65 units of nitrogen gave the highest yield at 46 cwt per acre. In 1969 where spring oats followed potatoes, there was, in contrast to 1968, a yield response to 90 compared with 65 units of nitrogen per acre. Grown as a second straw crop after winter wheat there was a substantial increase in yield from 34.7 to 39.4 cwt per acre with 60 and 90 units of nitrogen per acre respectively, indicating that the optimum level of nitrogen may have been in excess of 90 units per acre.

Irrigation effects on spring oats were investigated at Gleadthorpe Experimental Husbandry Farm in Nottinghamshire in 1965 and 1967 in combination with various nitrogen levels using the variety Condor. With 60 units per acre, an application of $1\frac{1}{2}$ in. of water at the late tillering stage increased yields in 1967, although in 1965 irrigation decreased yields except where 80 units of nitrogen were applied. Without irrigation, 120 units of nitrogen per acre, the highest level used, gave the maximum yield in both years.

In summary, work on the winter oat crop indicated that sowing the varieties Padarn and Peniarth in either mid-September or early October had little effect on yield, but if sowing of the latter variety was delayed until January or February yields were progressively reduced. Of the seed rates examined 140 lbs per acre gave the best yields, 30 to 40 units per acre was the optimum application rate for spring nitrogen: if this level was exceeded

lodging and reduced yields resulted in some years except possibly where a growth suppressant was used.

With the spring oat crop there was an indication that broadcasting could give similar yields to drilling in narrow rows. After a grazed ley a minimum of 40 units of nitrogen per acre was needed but following a cereal sequence, where oats as a break crop would be grown, the optimum level of nitrogen could be as high as 90 units per acre. On loamy sands as at Gleadthorpe E.H.F. a nitrogen application rate of 120 units per acre was used to advantage where the crop was not irrigated. On these soils irrigation at late tillering had a variable effect according to season.

BEANS

Winter beans

Experimental work on winter beans has been less than on the spring crop. At Boxworth in 1967 and 1968 the effects of a slow acting nitrogenous fertilizer (formalised casein) applied in the autumn, were compared with those of a quick acting fertilizer (ammonium nitrate/lime) applied late, just before the final hoeing. Both were applied at rates supplying up to 80 units per acre. In 1967 when the mean yield was 32 cwt per acre there was a yield response to the quick acting fertilizer at the highest rate of application. In 1968 when mean yields were only 15 cwt per acre there were no yield differences due to treatment.

Trials at Drayton in 1968 and 1969 compared two methods of seed bed preparation using either the plough followed by discing, or discing alone. Times of sowing were also compared, and Hasler's Throws was the variety grown at a seed rate of 2 cwt per acre and row spacing of 18 in. In the first year the trial was not harvested due to weather conditions. In 1969 an early sowing was not possible and instead a higher seed rate of 270 lb per acre was compared with the standard rate, both sown in early November and a late sowing was also made one month later. In this year, ploughing and discing gave an average increase in yield of 4 cwt per acre over discing alone. Delaying sowing until December reduced yields by over 5 cwt per acre due to a 30 per cent reduction in plant emergence. Increasing the seed rate for the November sowing had no effect on either plant population or yield.

Spring beans

Work at Boxworth has also been carried out for a number of years on the spring bean crop. In the four years since 1966, horse beans (variety Strubes) and tic beans (variety Minor) have been compared in trials at three seed rates and row widths of 8 in. and 24 in. Seed rates varied to some extent between years and the effects of a herbicide were also investigated at a wider row spacing. In the first two years the horse bean gave increased yields with increasing seed rates, confirming that a high seed rate was necessary with the larger sized horse bean to achieve a satisfactory population. Generally over the four years, except in 1968 when poor growing conditions masked any differences, Strubes outyielded Minor at medium to high seed rates (2 to 2½ cwt per acre) where a comparable number of seeds were sown per acre. Row width and herbicide effects were variable.

At Bridget's Experimental Husbandry Farm in Hampshire work with the spring bean crop began in 1967. For two years a trial compared three row

widths (7, 14, and 21 in.) and three seed rates (130, 160 and 210 lb per acre). Drilling was by a 7 in. 20 row drill with intermediate coulters blocked off as necessary, with which it was not always possible to achieve the maximum seed rates. In 1967 using the variety Blue Roc the highest seed rate was only achieved at the 14 in. spacing. This treatment gave an equal yield to the 7 in. spacing at the lowest seed rates, but yields were reduced when wider rows were sown at the lower seed rates. In 1968 seed rates sown were 130, 140 and 180 lb per acre and resulting plant populations were very variable, but the trend was for the higher seed rates to increase yields. Levels of nitrogen, phosphate and potash for the spring bean crop have also been investigated at Bridget's. 40 units per acre of both phosphate and potash were found to be adequate and no response to nitrogen was found in the 1967 crops, but in 1968 30 units of nitrogen per acre increased yields. A further trial in 1969 examined responses to higher levels of nitrogen application and yields were increased progressively up to 200 units per acre. Plant nodules were apparently healthy but the results should be regarded as unconfirmed because in both years mean trial yields were very low at only 15 cwt per acre.

Simazine is widely used to control weeds in the bean crop with good effect, except possibly in dry soil conditions. Earlier trials at Bridget's confirmed the value of this herbicide but experimental work in 1969 indicated that other materials (e.g., aziprotlyne, linuron and prometryne), may be as good as simazine.

Trials with aphicides at Bridget's have indicated that a routine treatment is probably worthwhile, at least in the southern counties. In 1966 there was only a moderate aphid attack and control although effective, was not economic. In the following year when aphid colonies were established before flowering there was little difference between types of aphicides used, but all gave over 6 cwt per acre increase in yield. In 1968 only small responses in yield to some aphicides were recorded.

The effects of different herbicides were also examined at High Mowthorpe in 1969 in a trial which also compared two seed rates (180 and 240 lb per acre), and two row widths (7 and 14 in.). Simazine, dinoseb/monolinuron, dinoseb acetate and dinoseb amine were used and of these simazine gave the best weed control but there was no effect on yields. Neither did differences in seed rate affect yields, although there was some advantage from drilling in narrower rows.

At Gleadthorpe in 1967 the effects of inoculating the bean seed with one of two rhizobium cultures were assessed either after a previous bean crop or after spring barley. The advantage of using an aphicide, disulfoton, was also examined and although it was found there was no control of aphids after mid-June an increase in yield of 2-3 cwt per acre was obtained from the aphicide where no inoculum was used. Only one inoculum, of Czech origin, increased yields but these were generally low at 12 to 13 cwt per acre. The previous cropping sequence had no effect.

In summary, work on the winter bean crop has so far shown that there was no difference between a slow acting nitrogenous fertilizer applied early or a quick acting one applied late. Ploughing and discing for the crop produced higher yields than discing alone. Delaying sowing of the variety Hasler's Throws until December reduced yields but increasing the seed

rate over 2 cwt per acre gave no yield response for a November sowing.

With the spring crop, horse beans generally outyielded tic beans at comparable seed rates. Work on seed rates indicated that for tic beans 200 lb per acre was about the optimum, and at lower rates than this rows wider than 7 in. reduced yields. 40 units of phosphate and potash per acre were sufficient on the chalky soils of South East England and here some response to nitrogen was recorded when growing conditions were not good. Simazine usually gave good control of weeds although this did not always lead to increased yields, but other materials now available were as effective. Aphid control was shown to be usually worthwhile regardless of the material used. Inoculation of the seed was possibly advantageous on a light soil.

OIL SEED RAPE

Although assessments of the effects of oil seed rape as a break crop have not been made in the trials described in the second part of this article, it is being grown as such in some parts of the country. Husbandry trials have been carried out on the spring sown crop only.

At Bridget's, trials in 1967 and 1968 compared three rates of nitrogen top dressing, above a basal rate of 80 units per acre applied in the seed bed, to give total applications of 100, 150 and 200 units per acre. Application of these levels in March, April or May was compared in 1967, and in April, May or June in 1968. In the first year 150 units gave the best yield but time of application had little effect either on yield of seed, which was about 1 ton per acre, or on yield of oil. In 1968 the mean yield of the trial was only 13 cwt per acre and there was little consistent yield response to more than 100 units of nitrogen. Again time of application had no effect on yield.

Control methods for pollen beetle and seed weevil were examined in 1968 when endosulfan and azinphos-methyl were applied either as wettable powders or miscible oils. Both materials in both forms caused a reduction in numbers of pollen beetles by mid-June and a slight increase in yield resulted. In 1969 there was a yield increase of over 2 cwt per acre from using 5 fluid ounces of gamma BHC per acre applied in late June.

At High Mowthorpe a trial was carried out in 1968 and 1969 comparing the effects of either broadcasting the crop or drilling it in 22 in. rows at seed rates of 3, 6 and 9 lb per acre with nitrogen dressings of 100, 150 and 200 units per acre. In 1968 6 lb of seed per acre gave the best yields, and there was no response to nitrogen above 100 units per acre. Broadcasting the seed gave some yield increases at the low seed and nitrogen rates, but no treatment had any effect on oil percentage. In 1969 better nitrogen responses were recorded and the highest level used gave the highest yield. The lowest seed rate was sufficient at the wide row spacing but 6 lb per acre gave the best yield when broadcast. In this year also broadcasting gave higher yields than drilling in 22 in. rows.

Nitrogen rates for the crop were also investigated at Gleadthorpe with 5 varieties at row widths of 4 in. and 20 in. 80 units of nitrogen were applied in the seed bed and additional top dressing made in late April to supply a total of 100, 150 and 200 units per acre. There was a mean yield for the trial of almost 17 cwt per acre but no differences in yield between treatments were recorded.

To summarize, the results of work on oil seed rape showed 6 lb was the optimum seed rate although this could possibly be reduced to 3 lb when the crop was grown in wide rows. Row width appeared to have little effect on yield but broadcasting was better than drilling in 22 inch rows. 100 units of nitrogen per acre were generally adequate although in some years responses to higher levels occurred. Five fluid ounces of gamma BHC per acre gave adequate pest control.

PEAS

The pea crop may also be considered as a break crop and when harvested for the dried pea trade can be tackled with conventional cereal harvesting machinery. Recent work on this crop has been restricted to Terrington E.H.F., where in 1967 and 1968 methods of harvesting have been under investigation. Maro was the variety grown in both years, and methods compared were cutting and tripoding, and cutting and windrowing, with and without the use of desiccants. The two desiccants compared were sulphuric acid and diquat, and in the first year they were applied either at time of cutting or 7 days later, whereas in 1968 they were applied 12 days after cutting when all pods were at the yellow parchment stage. In 1967 there was a heavy crop with short straw, little weed growth was present and harvesting conditions were good. Yields were not significantly affected by any harvesting method, but use of desiccant, especially sulphuric acid applied early, increased the percentage of stained peas. Pea colour was best where a desiccant had not been used. In 1968, when harvesting was more difficult, use of a desiccant actually reduced yields and tripoding gave the highest yield and the best seed colour.

HERBAGE SEEDS

Experimental work on herbage seeds was carried out at Bridget's E.H.F. on timothy from 1964 to 1966 and on S.321 perennial rye grass from 1967 to 1969. The experiments on timothy seed production compared: (a) row spacings of 3.5 in. and 21 in., (b) nitrogen rates of 60 units or 120 units per acre applied either in the first week of April or in the first week of May or split between the two, and (c) two systems of autumn management involving either no defoliation or cutting to ground level with a forage harvester. The 3.5 in. rows were drilled at 6 lb seed per acre and the 21 in. rows at 5 lb per acre, half the trial being sown in 1962 and the remainder in 1963. Seed production did not apparently decline over the trial period, and row spacing had little effect on yield, which averaged 2.85 cwt per acre of cleaned, dried seed. 120 units of nitrogen consistently produced yields of about 0.7 cwt more than 60 units, and application in April or as a split dressing gave a better yield than application in May. Defoliation in the autumn depressed the yield of seed by 0.5 cwt of cleaned seed per acre.

Investigations with S.321 perennial ryegrass at Bridget's have been concerned with harvesting methods. In 1967 an observation trial compared mowing and swathing with direct combining, both at three moisture contents. Showery weather during the trial period caused difficulty in drying and threshing the swathed plots and direct combining when the moisture content of the seed had fallen to 30 per cent was superior in terms of yield per acre and ease of operation.

In 1968 five times of harvesting S.321 by direct combining based on seed moisture content (ranging from 20 per cent to 40 per cent), and four beater speeds (from 1730 to 3170 feet per minute), were compared. Weather conditions were unsettled at harvest time, and the highest yield of uncleaned seed per acre was 13.9 cwt obtained from a crop harvested at 26 per cent moisture content and a drum speed of 3170 feet per minute. In 1969 the effects of a desiccant, diquat, were investigated at Bridget's again on S.321 ryegrass. In this year harvesting conditions were good so that a desiccant was not needed: its use caused a reduction in yield, probably due to wheel damage at time of application.

MAIZE

Although only grown on a limited scale in the south of the country maize may be used as a break crop in a sequence of cereal crops. There is some doubt about its resistance to take-all but it can be a good cleaning crop when the herbicide atrazine is used. No recent work has been carried out on Experimental Husbandry Farms on grain maize, but maize for silage is discussed elsewhere in this Report (see page 69).

Many aspects of the husbandry of these various break crops have been and still are under investigation at the Experimental Husbandry Farms. A break crop is not fulfilling its purpose unless it has some beneficial effect on the following cereal sequence, and an assessment of the value of break crops in this respect is made in the second part of this article.

*Part II*THE VALUE OF BREAK CROPS IN THE
ROTATIONE. J. Mundy, *Norfolk Agricultural Station*

and

M. Selman, *Boxworth Experimental Husbandry Farm*

The trend towards simpler arable farming systems has resulted in the practice of growing longer runs of cereals and successive cropping with wheat, and more particularly barley, is not uncommon. In such systems overhead costs of production can be kept relatively low but the yields obtained are usually less than those in a rotation. Trials on a number of Experimental Husbandry Farms have shown that the reduction in yield, compared to the first crop after a break, may be 20 to 30 per cent in the fourth and fifth successive wheat and barley crops. Results to date show that factors of soil fertility and structure, cereal diseases and pests, and grass weeds are all important as causes of decline in yield, the relative importance of these factors varying from farm to farm. The restoration of cereal yields following the introduction of break crops into a sequence of cereal cropping is the subject of a number of investigations being conducted on several Husbandry Farms. The choice of crops is influenced by:

- (a) the need to reduce diseases, pests and weeds associated with intensive wheat and barley growing,
- (b) the desirability of using the same machinery as for cereals,
- (c) the potential profitability of the crop, and
- (d) the possibility of building up soil fertility.

Crops that meet some or all of these requirements are beans, oil seed rape, herbage seeds, oats, possibly maize and in extreme instances a fallow or bastard fallow. There are of course other alternative crops but most of them involve a break from arable farming or require a higher capital and labour investment.

TRIALS IN PROGRESS

At Boxworth E.H.F. on calcareous clay in Cambridgeshire and at High Mowthorpe on chalky silty loam on the Yorkshire Wolds trials are being undertaken to evaluate the importance of one or two years break from intensive winter wheat. Oats, which are not susceptible to take-all, beans or fallow are being introduced as a one year break after the second and third successive winter wheat crops on land with a history of intensive cereal cropping. At both farms, the fallow was sown to mustard or rape, in the summer, as a precaution against wheat bulb fly, either to be ploughed in as a green manure crop or to be grazed by sheep in the early autumn. The two year breaks common to both farms are fallow/beans, beans/oats and two years of

late sown spring barley. Winter oats and winter beans were sown at Boxworth while at High Mowthorpe, which is the more exposed farm, spring crops were sown. Because of the possibility of late harvesting of the spring beans the oats followed the beans in the break. Late sown spring cereals afford an opportunity for spring cultivation to control weeds, for example wild oats, and the possibility cannot be ruled out that there might also be an effect on soil borne diseases. Cappelle-Desprez winter wheat was normally sown at both farms but because of the wet autumn and winter of 1968 it was not possible to drill the trial at Boxworth until the spring of 1969 when Rothwell Sprite was sown. Four rates of nitrogen fertilizer were given in the spring; these were 30, 60, 90 and 120 units at Boxworth and 40, 80, 120 and 160 units at High Mowthorpe. Two trial sites were laid down in successive years at High Mowthorpe while at Boxworth a second site was not established until two years after the first and has therefore not yet reached the testing stage of cropping after the break.

At Bridget's E.H.F. in Hampshire, on chalky silty loam, and at Drayton E.H.F. in Warwickshire on calcareous clay, simpler forms of the trials are being undertaken. At both farms one and two year breaks based on spring oats and beans are being introduced into continuous cereals (winter wheat at Drayton, spring barley and spring wheat at Bridget's) to study the immediate and long term effects of such a practice on crop yield and disease.

RESULTS

Winter wheat break crop trials

Since the trials described are still being phased in, results from the first year or two only are available and conclusions drawn must be regarded as subject to review when further information has been obtained.

TABLE I

*Yield of wheat following one year break 1968-9
cwt/acre at 85 per cent D.M.*

	Units of nitrogen/ac.				Mean
	N ₁ 30	N ₂ 60	N ₃ 90	N ₄ 120	
Boxworth					
High Mowthorpe	40	80	120	160	
Continuous winter wheat	22.9	26.4	31.5	32.2	28.2
Wheat after 1 year break of:					
Oats	25.6	30.8	35.3	36.5	32.1
Beans	29.8	36.3	35.7	35.2	34.3
Fallow or bastard fallow	30.5	36.2	38.1	36.6	35.3

The yield responses to treatments in the trials at Boxworth and High Mowthorpe show similar trends. Although there has been some variation in response to nitrogen between the years, the effect of the break crops has not been greatly influenced by year of harvest. The interim yield data for the effect of a one year break presented in table 1 are a mean of sites and years.

TABLE 2

*Yield of wheat following one and two year breaks 1969
cwt/acre at 85 per cent D.M.*

	Units of nitrogen/ac				Mean
	N ₁	N ₂	N ₃	N ₄	
Boxworth	30	60	90	120	
High Mowthorpe	40	80	120	160	
Continuous wheat 5th Crop	22.1	27.6	34.1	35.5	29.8
Second wheat crop after 1 year break of:					
Oats	20.9	26.0	32.5	34.9	28.6
Beans	21.5	25.5	34.3	36.0	29.3
Fallow	23.4	30.9	36.6	36.1	31.7
First wheat crop after 1 year break of:					
Oats	25.3	30.5	35.5	37.7	32.3
Beans	29.9	37.0	38.4	38.3	35.9
Fallow	27.7	36.1	38.5	37.9	35.0
First wheat crop after 2 year break of:					
Fallow/Beans	31.3	39.2	42.3	39.0	38.0
Beans/Oats	28.5	34.6	38.0	40.8	35.5
Late sown barley both years	22.0	25.9	32.1	35.3	28.8

The figures are thus the mean of three sets of data from High Mowthorpe and two from Boxworth. Within the range of nitrogen rates applied the optimum nitrogen requirement for continuous wheat was, with one exception,

higher than that for wheat after the break. At Boxworth 90 units of nitrogen per acre was the optimum rate for the continuous wheat crop and also for wheat after oats, while 60 units was adequate for wheat after beans and fallow. At High Mowthorpe the continuous wheat gave worthwhile increases in yield up to 160 units nitrogen which was the highest rate applied. Wheat following the one year breaks usually required 40 units nitrogen less, and wheat after beans up to 80 units less, than continuous wheat. The yield data in table 1 shows that wheat following a fallow yielded on average approximately 7 cwt more grain per acre than continuous wheat, whereas after beans and oats wheat yielded 6 cwt and 4 cwt more respectively. At neither site have pests been a problem and in 1969 the incidence of take-all was not as high as in 1968; however, it was apparent that all one year breaks greatly reduced the level of severe take-all infection but had little effect on eyespot.

Data on the yield of wheat following a two year break and as a second successive crop after a one year break, is limited to the 1969 harvest from one site at each farm and is presented in table 2. With the exception of a second wheat crop after a one year break of a fallow at High Mowthorpe, the yield of wheat in the second year after the one year break fell to a level similar to, or slightly below that achieved as a fifth successive crop. The break of two years late sown spring barley gave a mean increase in yield of 2.1 cwt over the continuous wheat at Boxworth, but at High Mowthorpe a fall in yield of 4.1 cwt compared with continuous wheat was recorded. The reasons for this different pattern are not clear and cannot be attributed wholly to an effect of weeds as there was no serious weed problem at either farm. The two year break of beans and oats increased yield by almost 6 cwt but showed no improvement over a single year break of beans. However two years clear of cereals (fallow/beans) gave a further 2.5 cwt yield improvement.

The incidence of take-all following a two year break from wheat or barley was negligible but control of eyespot was not apparent.

The trial at Drayton also suggests that beans are a better break crop than oats, for under conditions of adequate manuring the subsequent wheat crop gave up to 6 cwt more grain than crops following continuous wheat and 3.4 cwt more than after oats in 1966. In this trial Rothwell Perdix was the variety sown and yields were lower than normal due to attack by yellow rust. At both Boxworth and High Mowthorpe little benefit from a one year break remained for a second wheat crop whereas at Drayton, where grass weeds were competitive with the continuous wheat crop, the second wheat crop after the break continued to yield much better.

Spring cereal break crop trials

One year breaks of oats or beans and a two year break of oats followed by beans were introduced into a system of continuous barley growing at Bridget's E.H.F. Except for one treatment which remained in continuous barley the crop in 1969 following the break crops was Cappelle-Desprez winter wheat. Four levels of nitrogen fertilizer of 60, 90, 120 and 150 units per acre were applied to the cereals. Disease assessments indicated that all treatments were relatively free of severe take-all and severe eyespot. Much of the crop

however was affected by slight take-all and eyespot infection, the wheat after continuous barley carrying the highest levels.

There was a good response to nitrogen and the optimum level for the continuous barley, wheat after continuous barley, or wheat after the one year break of beans was 120 units of nitrogen. Wheat after the one year break of oats and after the two year break gave a worthwhile response to nitrogen continuing up to the highest rate of 150 units. The yield of wheat after continuous barley was 37.6 cwt per acre where 120 units of nitrogen had been given, this was 1.1 cwt more than the yield of continuous barley. At the same level of nitrogen the two year break increased the yield of the following wheat crop by 1.8 cwt compared with wheat after continuous barley, and the one year break crops of oats and beans gave a further yield increase of 1.6 and 3.4 cwt respectively.

An almost identical trial introducing a one year break of beans and a two year break of oats and beans into a system of intensive spring wheat gave similar results.

In this trial the incidence of severe take-all and eyespot was also low and Kolibri spring wheat yielded 31.5 cwt where 150 units of nitrogen had been applied. This level of nitrogen gave the best results for each treatment except after a one year break of beans where 120 units proved adequate. At the optimum level of nitrogen for each treatment continuous spring wheat yielded 31.5 cwt, which was 2.5 cwt less than the wheat after the two year break and 3.5 cwt less than after the one year break. In this trial wheat as a second crop after the one year break gave a similar yield to that of continuous wheat.

DISCUSSION

The results so far obtained from all the trials reported above show that the introduction of one and two year breaks improves the yield of the succeeding cereal when compared with continuous cropping. In 1969, a year when take-all and eyespot were not serious, the one year break of beans gave as much benefit as the two year break. Where the limiting factor to the success of intensive cereal growing is weeds the introduction of clean break crops is likely to give longer lasting effects. However where wild oats are a problem the capacity of the seed to lie dormant over a number of years will mean that the problem cannot be cured by short term break crops alone.

In situations where long runs of cereals are giving satisfactory yields and soil structure is being maintained, the introduction of a one year break crop is unlikely to give lasting benefit and may possibly lead to reduced yields in the years subsequent to the one following the break. The results so far obtained in the trial series described would support this view. However there are instances where benefits from introducing a break crop have persisted for several years. On a different site at Boxworth the yield of wheat following the introduction of a one year break of beans after 12 or 13 years of continuous wheat gave a detectable improvement in yield for three subsequent years. The introduction of a longer break, possibly a ley, or a return to a balanced rotation is likely to be of greater benefit to cereal yields than the one year break. The present series of trials is however still in progress and conclusions drawn should be considered as tentative only.

IRRIGATION OF FARM ARABLE CROPS

L. W. Wellings, *Gleadthorpe Experimental Husbandry Farm*

In the lower rainfall parts of Britain moisture is often considered to be the main factor limiting crop yield. Irrigation can be used to overcome any moisture deficiency but this is only a practical possibility if the returns from irrigation exceed the costs of applying the water.

During the last 15 years, work at Gleadthorpe E.H.F. has built up a body of evidence on the watering requirement of agricultural arable crops and the responses that can be expected. In future this information will be supplemented by data from experiments on Arthur Rickwood E.H.F. as well as Gleadthorpe. Each crop has its own irrigation requirements and it is most convenient to consider each one separately.

POTATOES

Potatoes have proved to be the most responsive arable crop to irrigation. Studies on irrigation frequency have shown differing water requirements and yield responses for early and maincrop varieties.

Early potatoes

Early potatoes grow for a relatively short time so that any period of moisture stress might be expected to lead to lower yields. Study of the watering requirements of the crop from 1960-1963 compared the effect on the yield of Arran Pilot and Ulster Prince of either no irrigation or watering when the soil moisture deficit reached 25, 50 or 75 per cent of the available moisture in the top foot of soil. The varieties reacted differently. When Arran Pilot was allowed to dry out until 75 per cent of the available moisture in the top foot had been used before returning it to field capacity, the yield response was smaller than when watering was more frequent, but Ulster Prince withstood this degree of stress without yield loss.

With early varieties, where the objective is to produce the maximum yield as early as possible in order to obtain the best price, the conclusion drawn from the evidence of these trials is that water should be applied whenever the deficit reaches 60 to 70 per cent of the available water in the top foot of soil.

Over the period 1960-68 responses were obtained to irrigation in every year except 1965 when the weather was wet throughout the growing period. The average response was 35 per cent increase in yield and was financially well worth while.

Maincrop potatoes

Studies on the watering requirements of maincrop potatoes indicate that the crop is more tolerant of dry conditions than early potatoes. Allowing the soil moisture deficit to reach the equivalent of the total available water in the top foot of soil has had no significant effect on crop yield compared with more frequent watering, although there has been a tendency for the yield to

be higher where the moisture stress was slightly less. Current work at Gleadthorpe is investigating this further and subjecting the plant to a deficit equal to the available water in the top 18 in. of soil before restoring it to field capacity.

A single year's result showed no differences in response whether the crop was watered frequently or irrigation was withheld until the deficit had reached the available water in the top 18 in. of soil. This result needs to be treated with caution until further trial work has been done. Reducing the frequency of application is attractive because it reduces the labour requirements for moving equipment and also there is less chance of irrigation being wasted when it is quickly followed by rain.

Yield responses to irrigation do not occur in every season and an assessment of the average yield increase needs to be made in order to determine the potential value of irrigation. Data on the effect of irrigation on potato yields is available for a fifteen year period at Gleadthorpe E.H.F. In nearly half the years there was no response to irrigation even though a soil moisture deficit occurred sometime in the life of the crop. There were major responses in only three years, when conditions were very dry, and in the remaining years responses have been moderate. The average yield increase has been 2 tons per acre and the average water application $3\frac{1}{2}$ acre-inches per year, a response of 0.6 tons per acre-inch applied. This response is below those frequently quoted because all the water applied has been debited against the total yield response even though some of it has had no effect on crop yield.

Control of common scab by irrigation (see plate II)

Correctly timed irrigation can give good control of common scab. Work at Rothamsted and overseas has shown that tubers are attacked by the disease when soil conditions are dry and that tubers are most susceptible for a period of 3-4 weeks following the initiation stage, which is just as the stolon tips begin to swell. Using frequent irrigation to keep the soil near field capacity, tubers were produced which were entirely free from scab, but this practice would be too costly for commercial production. Current work at Gleadthorpe E.H.F. in co-operation with Rothamsted is aimed at developing commercially viable methods of scab control by watering. A tentative recommendation from results so far is that the soil should be returned to field capacity when the crop covers 10 to 20 per cent of the soil surface, and if weather conditions are very dry a further $\frac{3}{4}$ to 1 in. of water should be applied within a week of the first irrigation. If the first watering is followed by wet weather, then one watering should be sufficient to give commercially acceptable control of the disease. Following this treatment to control scab, normal irrigation should be continued to allow the crop to bulk and express its full potential. Wet soil conditions at tuber initiation often lead to a larger number of tubers being formed. While this is a distinct advantage with those varieties which produce low tuber numbers it can be a serious disadvantage with varieties which have a high tuber number, and occasionally serious reductions in ware yield have been recorded in such cases. This effect can, however, be used to good advantage in the production of canning potatoes where high numbers of small potatoes are required.

SUGAR BEET

Sugar beet has a deeper rooting system than potatoes so that it can explore a bigger volume of soil. An analysis of the data obtained from trials at Gleadthorpe E.H.F. shows that the crop can tolerate a deficit equal to the available moisture in the top 2–2½ ft of soil without yield being reduced. This means that irrigation need is infrequent, even on the lighter soils. Studies on the irrigation of sugar beet at Gleadthorpe between 1955 and 1968 showed that major yield responses occurred in only three years when the weather was abnormally dry. The average yield increase over the fourteen year period was 2.9 tons per acre and the average water application 2.7 acre-inches, a response of only 1.1 tons per acre-inch applied.

CEREALS

Irrigation of cereals over the period 1961–68 showed an average yield increase of 3 cwt of grain. Studies on the timing of water application for winter wheat and spring barley have shown that wheat responds best to water applied just before ear emergence (boot stage) rather than applying it at the late tillering stage, whereas barley gave a similar response to water applied at either stage. 1½ acre-inches applied at the optimum stage for each cereal gave a similar yield to 1½ acre-inches applied at both the late tillering and boot stages.

These trials were done in a series of wet springs but observation during dry conditions in June and July when rainfall was only 1.5 in. following a wet May in 1967 suggests that moist conditions early in a crop's life are more important in obtaining a good yield than moisture during the grain filling stage. The evidence of the trials suggests that irrigation of cereals is only likely to be economically worth while in dry springs but there is a need for more information on responses when such climatic conditions occur.

CARROTS

Carrots, once regarded as a horticultural crop, are now being grown increasingly on a farm scale. Many crops receive irrigation and the results of six years work at Gleadthorpe E.H.F. give pointers to yield responses and the water requirements of the crop.

Over this period significant yield responses to irrigation were only obtained in the dry conditions of 1967, showing that established crops of carrots can tolerate moderate moisture deficits. In 1967 allowing the deficit to reach 3 in. before watering had no detrimental effect on yield compared with applying ¾ in. whenever the deficit reached 1¼ in. Deficits in excess of 3 in. occur infrequently under commercial systems of production so the irrigation need is likely to be infrequent.

CONCLUSION

Irrigation studies over a long period of time at Gleadthorpe E.H.F. have shown that most agricultural arable crops give limited responses to irrigation, and potatoes are the only single crop for which expenditure on irrigation

equipment can be justified. Irrigation requirements of many crops do however occur at different times during the year e.g., cereals in May, early potatoes in May–June and sugar beet in July–August, so that the same equipment can be used for a number of crops. The results of the experimental work suggest that a grower should think in terms of suitable rotations to give a number of crops which have water requirements at different times if he wishes to make the best use of investment in irrigation.

REDUCED CULTIVATIONS FOR CEREAL GROWING

J. E. Whybrew, *Drayton Experimental Husbandry Farm*

The introduction of paraquat in the last decade stimulated a lot of interest in the possibility of growing cereals and other surface harvested crops such as kale, with little or no disturbance of the soil.

To this end, a philosophy of direct drilling into undisturbed soils was developed by Messrs. Plant Protection Ltd., and was examined by five Experimental Husbandry Farms, Boxworth, Bridget's, Gleadthorpe, High Mowthorpe and Rosemaund, on soil types varying from loamy sand through chalky silty loams to silty clay loams and calcareous clays.

The work has now been concluded and was reported by Wellings in the Proceedings of the 9th British Weed Control Conference, 1968.

The intention was to compare direct seeding into undisturbed soil, reduced cultivations (rotary or tined cultivators being used) and traditional seed bed preparations following ploughing; to record their effect on the yield of winter wheat and spring barley; to examine the nitrogen requirements of such systems; and to study the effects of the different systems on soil structure, organic matter status, etc., over a long run of years.

The trials were arranged on a replicated plot basis with phasing to take into account variation between seasons.

The progress of the experiments was reviewed each year and it became clearer at each succeeding year that the problems created by the three systems were not capable of solution within the context of the formal experimental approach.

One major difficulty at most centres was the limitation imposed by small scale plots on effective cultivations. For example cross cultivation following ploughing was difficult if not impossible to carry out, and this was considered to have had an adverse effect on the yields of cereals after ploughing at Boxworth. In all cases the starting point of each experiment was after a ley which was killed by paraquat.

During the course of the experiments it was found that in well knit swards the recommended dose of 4 pt paraquat per acre was often insufficient to kill all the grass, especially if the sward had not been grazed down well or closely mown prior to spraying. This meant that a further spraying was necessary with a considerable increase in cost, before the site was considered suitable for further operations. Two slit seeding drills, kindly loaned by Messrs. Plant Protection Limited, were used originally for drilling all sites but were replaced by triple disc drills when they became available at a later date.

From the outset it was clear that penetration of undisturbed soil of any texture was going to be difficult, especially in dry conditions. Deeper penetration was achieved to some extent, by increasing the weight of the drill; but this then had detrimental effects on the soil itself and the observation was made at Rosemaund E.H.F. that germination was poor where the seedbed had been over run by the drill wheels.

Penetration was more successful in moist soils, but this then gave rise to a further problem of slits remaining open and leaving the seed vulnerable to the depredations of birds and slugs. Slugs were a major problem at Bridget's and Rosemaund. However, some degree of success was achieved by harrowing the slits after drilling.

Successful establishment of a crop is one of the most important factors in controlling weeds within the crop. In many cases direct drilled crops suffered from poor establishment and this led to aggravated weed problems, especially where perennial weeds were present. A further unsuspected factor, which became obvious as the trial progressed, was that many apparently clean, uniform, and well managed swards masked the presence of couch and other perennial weed grasses. The spread of these grassy weeds was also helped by the use of low levels of nitrogen on some plots and also the use of blocked coulters to define the harvest area.

The current herbicides available for controlling rhizomatous grasses are not very efficient without incorporation into the soil by cultivations. In some cases this absence of soil disturbance has enabled couch to gain the upper hand and has resulted in lower yields.

One further point was the tendency of slits cut into clay soils to smear which trapped considerable amounts of water. This led to waterlogging, another reason for poor plant establishment.

In spite of these vicissitudes little evidence accumulated to suggest that ploughing had an irrefutable advantage over other methods of seedbed preparation and drilling, or that disease was more rife where stubble residues were left unburied. So long as plant establishment was good and there were no weed problems average yields of direct drilled crops were 8 per cent lower than conventionally grown crops. On the other hand, limited disturbance of the soil gave yields which varied according to the soil. Generally speaking, rotary cultivation gave results which were as good on light soils as traditional systems, but which worsened as soils got progressively heavier and more difficult.

Stubble residues hindered drill penetration in some situations, especially where straw was baled rather than burnt. This was more noticeable on the direct drilled plots and was less of a problem following cultivation or ploughing. These problems all contributed to a decision to conclude the formal experiment after four years' work, but the experience gained on the farms has led to a continuing interest in the possibility of reducing cultivations to less than those traditionally regarded as necessary for the growing of good cereal crops.

The economic spurs for this are powerful. For instance, labour is leaving the land at a rapid rate and in the case of hired labour it is usually the most skilled that seek their fortune outside agriculture; thus ploughing, an operation requiring considerable skill, is not carried out as it should be. The man hours available for seedbed preparations are reduced as manpower is spread

more thinly over an increased arable acreage, especially where winter wheat is the major crop and the time available for working down seedbeds between harvest and drilling is reduced by bad weather. Since ploughing is a relatively slow operation on heavy soils where much autumn sown corn is grown, the possibility of reducing tractor hour requirements from five to two hours per acre assumes great importance, because cultivations can be carried out rapidly and when soil conditions are more nearly optimum. Any seedbed preparation system must be a sequential one, although on light soils the sequence may be short with small intervals between operations. In this situation perhaps there is little to be gained from a reduced cultivation system.

However, the omission of ploughing from seedbed preparation on heavy soils immediately reduces the need for a skilled operator and cuts down the time required to create a seedbed by as much as three hours per acre. On the debit side, reduced cultivations can lead to increasing weed populations. In the past weeds were controlled to some extent by ploughing under germinated seedlings in the autumn, but surface cultivation does not invert the soil, and its weed killing capacity especially in the autumn, is therefore much less.

In the category of autumn germinating weeds, shed grain which germinates after harvest should also be included.

However, the situation can be controlled by light doses of paraquat, as low as 4 oz a.i. or 1 pt of product per acre, which gives satisfactory control of weed seedlings, and germinating shed corn. They can be applied just before drilling so that the germinating seed is freed from competition with established weeds.

Present work

As a result of the experience gained with the original co-ordinated trial it has been recognized that meaningful experiments on cultivations are difficult to carry out in the formal trial layout. Plots need to be large enough to enable farm machinery to work satisfactorily and treatments to be kept as simple as possible. Because of this, work on the E.H.Fs. is now taking the form of locally initiated studies on various aspects of cereal cultivations.

All the farms seem to have come to the conclusion that direct drilling is not a viable prospect on their own particular soils and that future work should be aimed at the production of seedbeds by reduced cultivations and the use of chemicals to control weeds, rather than by the elimination of cultivation altogether.

Boxworth is at present collaborating with the N.I.A.E. in examining various alternative primary cultivation systems, using different combinations of chisel ploughs, rotary cultivators fitted with a seedbox, and shallow ploughing.

High Mowthorpe is concentrating upon the solution of the weed problem raised by the original trial using cultivators, or cultivators and chemicals, to reduce couch infestation on land destined for spring barley.

Drayton is examining two seedbed preparation methods, disc harrows, and chisel ploughing compared with conventional ploughing for cereals and winter beans.

Bridget's is examining the possibility of using a cultivator instead of a

plough and also of reducing the number of cultivations required to produce a seedbed in the spring.

Much useful information albeit of a somewhat subjective nature, is being accumulated about the potential of reduced cultivations for cereal production.

RESULTS

Much of the work briefly mentioned above is in its early stages with few conclusions to be drawn as yet, but observations at Boxworth and Drayton may serve to indicate the direction in which things may be expected to move. At Boxworth, on chalky boulder clay, a 35 acre field unploughed since 1963 has grown cereals continuously since 1961, and barley continuously since 1964. The 'normal' method of seedbed preparation has been to use a cultivator instead of the plough. Yields have averaged between 38 and 42 cwt per acre for the last five years with the exception of 1968 when, because of the appalling season, yields fell to 30 cwt per acre. The yield of 38 cwt per acre in 1969 was among the highest barley yields on the farm that year.

One interesting observation has been that couch infestation which seemed to increase from 1961 to 1963 has been reduced over the years to minimal proportions. The yields are well within the range of crops grown after ploughing, and the inference may be drawn that reduced cultivations do not necessarily result in reduced yields.

The work on reduced cultivations for cereals has been followed with keen interest at Drayton E.H.F. (although the farm did not participate in the original experiment) and observations on this Lower Lias clay farm prompted some work into the growing of the winter bean crop in which ploughing has been replaced by tined cultivation and once again yield differences have been small. The wet autumn of 1968 was the spur which encouraged the adoption of a no ploughing regime over a large proportion of the cereal acreage. The land was too wet to plough and prepare seedbeds in the traditional manner. However tined and disc cultivators enabled the scheduled acreage of winter wheat to be sown successfully, using unorthodox methods of preparing seedbeds and of seeding when the occasion demanded. The results at harvest suggested that the yields of winter wheat after ploughing of 34 cwt per acre over some thirty acres were not materially different from a yield of 33 cwt per acre over some seventy acres which were cultivated only. The yield of the ploughed acres was substantially increased by 10 acres which followed a one year ley that had been mole drained, mucked and ploughed out in July and which yielded 43 cwt per acre.

The important factor, apart from yields, was the time required for preparing seedbeds. This averaged out at 1.5 tractor hours per acre for cultivating and 4.7 tractor hours per acre for ploughing, so that the potential for rapid work was greatly increased by the omission of ploughing and the judicious use of chemicals for seed bed weed control.

Good cultivation of the soil is still an art rather than a science and it will remain so until some simple objective methods of describing and/or predicting optimum soil conditions are developed.

However, progress is being made, and the realisation that herbicides can be used to supplement purely mechanical processes has at least opened the way for a new appraisal of cultivation systems for modern cereal husbandry.

MULTI-LEVEL NITROGEN TESTS FOR CEREALS

D. A. Boyd, *Rothamsted Experimental Station*

The starting point for this new series of experiments was some fresh information on the relationship between nitrogen dressings and crop yields. As much for statistical convenience as from physiological reasoning this relationship, usually called the 'response curve', has generally been assumed to follow a simple curve, of exponential or quadratic form. In the past, most experiments tested only 3 or 4 amounts of nitrogen, too few to give more than a very general indication of the response curve. However, examination of two series of experiments testing 5 and 6 amounts of nitrogen for sugar beet* showed that, for sugar yield, response to nitrogen was often less well represented by a curve than by two straight lines. A similar finding for cereals could affect manurial recommendations and so the new experiments will test many dressings of nitrogen.

Typically, increasing amounts of nitrogen at first increase sugar yield rapidly and almost linearly. When still more nitrogen is given, yield of tops goes on increasing whereas for sugar yield there is a quite sharp transition to a second line with yield changing little or even decreasing slightly. It seems that once a critical leaf density has been reached, depending on characteristics of the site, crop and season, nitrogen cannot increase sugar yield further. This situation resembles the so-called 'Law of Limiting Factors' put forward by Liebig over a century ago.

There is good reason to think that, for cereals also, a more detailed knowledge of the form of the response curve, coupled with a more systematic investigation of the reasons for differences of response from place to place, and year to year, could help growers to anticipate their crops' needs more correctly. Preliminary tests of seven amounts of N, from 40 to 160 units N per acre, made in 1969 with a seventh successive winter wheat crop at High Mowthorpe, and of eight amounts from 0 to 105 units N per acre, made with spring barley at Rosemaund, were each well fitted by a single straight line, whereas the responses to eight amounts from 40 to 180 units N per acre on the thirteenth successive barley crop at Boxworth were well represented by two straight lines, the optimum being about 120 units N per acre. In addition, a small series of experiments with spring barley has already been completed in the N.A.A.S. South Western Region, and others testing six amounts are in progress in the Northern and South Western Regions. These suggest that for cereals also the idea of representing response to nitrogen by one or two straight lines may prove a useful one. Although results for most sites seem to conform to this pattern, the nitrogen/yield relationship is likely to be more complex than for sugar beet. Thus it would be surprising to find that the indirect effect of nitrogen through disease and lodging always affected yield linearly.

*Results of these and other experiments with N for sugar beet are given by Boyd, Tinker, Draycott and Last, *J. agric.Sci.*, **74**: 37-46 (1970).

Yields of grain from multilevel nitrogen tests on three E.H.Fs. 1969
(cwt/acre)

	units N/acre								S.E. ±
	40	60	80	100	120	140	160	180	
High Mowthorpe	15.9	18.8	21.6	25.2	28.7	30.4	30.7	—	0.81
Boxworth	24.2	26.3	28.7	31.2	31.6	33.5	33.0	23.9	0.84

	units N/acre								S.E. ±
	0	15	30	45	60	75	90	105	
Rosemaund	17.2	23.4	22.4	29.0	32.3	32.8	36.8	39.9	1.79

For both crops the relative importance of the two portions of the nitrogen/yield relationship differs greatly from experiment to experiment: on some sites responses were solely on the upper portion of the curve, indicating that the soil was rich enough to supply all the nitrogen needed by the crop, or where yields were poor that some other factors inhibited response to nitrogen. In contrast to sugar beet, some cereal crops show large yield decreases from extra nitrogen once the transition point is reached; indeed, at Woburn in 1968 the yield of spring barley decreased almost linearly from 32.5 cwt per acre with 40 units N per acre to only 23.5 cwt per acre with 160 units N per acre. On most sites response on the rising portion of the response curve is about 25 cwt per 100 units N for both sugar and grain yield (the similarity has no physiological significance), but on some sites the rate of increase is much less; the transition point may then not be reached without very large dressings, as at High Mowthorpe in 1969, when the unusually wet spring may have leached nitrogen before it could be taken up by the growing plant. Diseases and poor soil conditions could have similar results. An important aim of the new investigations will be to try to explain such differences in response from place to place, and from year to year, and to see how far they can be predicted.

HERBICIDES FOR WILD OAT CONTROL

M. Selman, *Boxworth Experimental Husbandry Farm*

The two herbicides currently in common use for the control of wild oats are the soil-incorporated spray tri-allate, and barban which is applied post emergence. Each has disadvantages. Tri-allate requires a good tilth for its incorporation and this may be difficult to produce in the autumn for winter

wheat: on the other hand, if the soil is worked too much at this time it may subsequently run together and form a cap. For both autumn and spring crops the extra cultivations required for the incorporation of tri-allate must be done at a busy drilling time. Barban must be applied in the spring when the wild oat seedlings have about two leaves, but unfortunately the wild oats do not all reach this stage at the same time, particularly in winter sown crops. In practice one must try and catch the majority at the critical time, when all too often the weather is an obstacle. Barban also needs a strong, competitive cereal crop if it is to have its best effect on wild oats. Furthermore where barley is being grown the choice of variety is limited to those tolerant to barban.

Neither of these herbicides give complete control of wild oats and there is a great need for a more potent, selective material and especially for one which is more flexible in its use.

At the 9th British Weed Control Conference, 1968, Holroyd from the Weed Research Organisation reported very promising results from a granular form of triallate. This had been effective at 1.0 to 2.0 lb a.i. per acre applied post emergence without incorporation. Many wild oat plants with three leaves plus tillers had been killed.

Boxworth was one centre amongst many where tri-allate granules were tested in 1969. Granules were applied to a crop of spring wheat (*var.* Rothwell Sprite) in three different ways:

- 3 lb a.i. per acre applied soon after drilling and incorporated;
- 1½ or 3 lb a.i. per acre applied after the bulk of the wild oats had emerged;
- 1½ or 3 lb a.i. per acre applied after the wild oats had commenced tillering.

These treatments were compared with tri-allate as a spray incorporated after drilling at 1½ lb a.i. per acre. The best control of wild oats was achieved by granules at the 3 lb rate incorporated after drilling. This treatment resulted in considerable crop thinning, but grain yields were not affected. No other method was better than spraying although 3 lb per acre applied when the wild oats were tillering showed some promise. Wild oats germinated over a long period at Boxworth in the late spring of 1969 and it was difficult to decide when to carry out the later treatments. The use of granules soon after drilling was the most successful treatment at many other centres.

In 1970 there will be a modified trial on winter wheat. This will compare tri-allate spray at 1½ lb a.i. per acre at drilling with 1½ lb a.i. granules at the same time, incorporated or not incorporated. Further treatments will be granules at 2 or 3 lb a.i. per acre, or 5 oz barban when the wild oats have one to two leaves.

The granules contain 10 per cent tri-allate. They have the advantage that no water need be transported, though, of course, an applicator is required.

In 1969/70 four herbicides are being tested for the control of blackgrass at Boxworth. These are methabenzthiazuron, metoxuron, tri-allate and terbutryne. It is also intended to compare the first two with tri-allate for their effectiveness against wild oats. Mixed infestations of wild oats and blackgrass often occur in winter sown crops on heavy land, and a dual purpose spray would have considerable advantages.

THE MECHANICAL PLANTING OF SPROUTED MAINCROP POTATO SEED

F. E. Shotton, *Terrington Experimental Husbandry Farm*

When farmers first started to use machines to plant potatoes the planters were usually 'hand assisted', that is operators – usually one per row – rode on the machine and transferred the seed potatoes by hand from chitting trays or hoppers into the planting mechanism. There was some concern that the chits should not be knocked off sprouted seed and that seed should be carried down to the ground and not allowed to drop a great distance, but in general any discussion concerned the cost of the machine and the speed of planting rather than the eventual crop yield. There were in fact trial results (e.g., at Terrington during the 'fifties) which showed that, as a system, hand-assisted machine planting could give higher yields than hand planting – probably because of reduced moisture loss. These findings have been repeated in a current series of trials at High Mowthorpe.

From about 1963 a new type of planter began to be imported from the continent, mainly Germany. These so-called 'automatic' planters did not require operators to handle the seed tubers. The seed was picked up by cups on an endless chain from hoppers into which it had been tipped from the sacks or chitting trays. The spacing given by such machines was very accurate because if a cup failed to pick up a seed the deficiency was made good by the 'corrector' mechanism. The job of any operator who might ride on the back of a multi-row 'automatic' machine was to service these 'correctors'.

With unsprouted seed these machines could do excellent work. When sprouted seed was used it was however quickly evident that in some cases many of the sprouts were being knocked off and that seed tubers were being bruised as the chain of cups stirred through a depth of tubers in the hopper. Shutters were provided to control the flow of seed from the main to the pick-up hopper and were intended to prevent this sort of damage but their accurate regulation did not always prove possible. Farmers who had the opportunity to compare the work of these 'automatic' machines with that of hand-assisted planters or hand labour gangs frequently commented that emergence was slower behind the 'automatic' machines. Occasionally they found unexpectedly severe gapping due to greater development of seedborne diseases, when these machines had been used.

The suggestion was made that damage to the seed might be reduced if the sprouting system were modified to ensure that only short sprouts were produced. Trials were started at High Mowthorpe in 1967 to compare systems of planting using unsprouted, short-period sprouted and normally sprouted seed. During the first two years the yield from unsprouted seed was practically the same no matter whether it was planted by hand, by hand-assisted planter or by a fully automatic planter. But with either type of sprouted seed the hand-assisted planter gave the best and the fully automatic continental planter the worst results.

It was noted that with hand and hand-assisted planting, normal sprouting gave a yield increase of 1.3 to 1.4 tons per acre over unsprouted seed and that short period sprouts gave about half this advantage. When planted with

the automatic planter the advantage of sprouting was largely lost. The former results are in good agreement with figures from several years trials at Terrington. Using King Edward and Majestic the traditional type of sprouting for 8 weeks or more gave yield increases of about $1\frac{1}{2}$ tons per acre. During recent years when comparisons with shorter period sprouts have been included, a brief sprouting period of about 3 weeks has given 0.4 tons per acre less King Edward ware than normal sprouting and, in a single trial with Majestic the reduction was 1.4 tons per acre. Terrington trials have however indicated a contrasting result with the new varieties Pentland Crown and Pentland Dell. When these were *hand planted*, sprouts produced in a short period outyielded older sprouts (by an average of 0.9 tons per acre over 3 years in the case of Pentland Crown).

*Mean total yield of Majestic grown at High Mowthorpe in 1967 and 1968
(tons/acre)*

Method of planting	Type of sprouting			
	Unsprouted	Short period	Normal	Mean
Hand planted	8.5	9.0	9.8	9.1
Hand-assisted planter	8.9	9.8	10.3	9.7
Cont. automatic planter	8.6	8.9	8.9	8.8
Mean	8.7	9.2	9.9	9.2

The damage caused by the planter mechanism to sprouted seed has also been studied in trials at Terrington. In 1968 this was done by passing seed through the mechanism of a stationary continental automatic planter: in 1969 by collecting seed during the process of planting with three types of planter. Results were as follows:

Percentage of sets having all sprouts removed or severely damaged

	Type of sprouting	
	Normal	Short period
1968 Pentland Dell		
Continental automatic planter	48	79
1969 King Edward		
Hand-assisted planter	26	26
English automatic planter	28	40
Continental automatic planter	46	64

It will be seen that in both years the continental automatic planter caused a very high level of damage to sprouts. Except when the hand-assisted planter was used damage was always markedly more severe on sprouts produced in a short period than on normal, older sprouts. The younger sprouts were usually about 7 to 12 mm ($\frac{1}{4}$ to $\frac{1}{2}$ in.) long and as such they were just a little shorter than the normal sprouts. It must be emphasized that the sets did not merely have opened eyes which earlier trials at Terrington had shown to yield much less well than normal sprouts.

The type of sprouts and the degree of damage which they suffer during planting have usually shown a fairly clear relationship to the time taken for 75 per cent of the sets to emerge. Old, undamaged sprouts of over 12mm in length came up quickest; younger, shorter or damaged sprouts take longer to emerge.

The harvest yields from a number of trials are in conformity with the data for sprout damage and speed of emergence. There are however certain anomalous results from both farms which cannot at present be fully explained, and which are probably due to such factors as seedborne diseases or the weather at the time of tuberisation over-riding or interacting with the experimental treatments in an unusual way. But on a broad view of the trial results so far available it seems probable that the High Mowthorpe data already quoted will be found to give a very reasonable expression of the average results for the older varieties. Terrington evidence shows that short period sprouting for Pentland Crown and Pentland Dell is superior when they are to be hand planted. These results might also apply if these varieties were planted by a hand-assisted planter and in a 1969 trial with Pentland Crown the short-period sprouts gave a good performance when planted with the Continental planter. This was however not the case in the 1968 trial with Pentland Dell when, after being passed through the mechanism of the Continental planter, seed which had had a long sprouting period yielded better.

On the basis of these trial results one cannot welcome with any degree of enthusiasm the further extension of the use of the Continental type of planter for sprouted seed. It seems questionable whether its greater speed of planting will make up for the probable reduction in yield due to sprout injury. Nevertheless speed of planting is valuable and the labour economy of automatic planters is essential on certain farms where hand labour is particularly scarce. The 1969 trials at Terrington included a third type of planter—the English automatic. This is the belt-fed planter developed over recent years from the N.I.A.E. bulb planter. On speed of planting it is superior to the Continental automatics and in the trial, as will be seen from the table on p. 42, it caused very little more damage to normally sprouted seed than the hand-assisted planter. On these two counts it is at first sight very attractive for use with sprouted seed. This machine lacks the precision of spacing which the Continental planters give and in the hands of careless operators its spacing can be highly erratic. With careful setting and supervision gross irregularity of spacing can be avoided, and the effect of this residual degree of irregularity on both yield and the evenness of the ware sample is a subject of great current interest to potato growers, especially those with large acreages. A start has been made at Terrington on the examination of this very complex problem and preliminary results may be expected after the 1970 season.

Planting is of course merely one step in the husbandry of the crop. While it may be necessary to examine separately in experiments the various parts of the process it would be wrong to draw over-hasty conclusions based on a consideration of only one factor such as the speed of operation of a particular planter. What the grower should consider is the effect of his planting practices, not only on the speed and labour economy of planting, but also on other factors such as the ease of harvesting, the crop yield and, above all, the overall profitability of the crop.

WIDER ROWS FOR POTATOES

R. H. Jarvis, *Terrington Experimental Husbandry Farm*

Traditionally maincrop potatoes have been grown in rows 27 or 28 in. apart. This row width seems to have been determined largely by the requirements of horses and horse-drawn equipment and is in many ways unsuitable for modern mechanized methods of husbandry. In the main potato-growing districts most farmers have already changed to a row width of 30 in. but there is no doubt that in some cases appreciable benefits could be obtained by increasing the row width still further. In wider rows the length of row per acre is reduced; the number of headland turns per acre is lower; there is more room for tractor tyres between the rows; and inter-row cultivations need be less deep to produce the same amount of tilth. But although these points are important, the most important factor is the effect of row width on yield.

In trials carried out at Terrington E.H.F. from 1965 to 1969 with King Edward, Majestic and Pentland Crown, the yield of saleable ware increased by $\frac{1}{4}$ – $\frac{1}{2}$ ton per acre when the row width was increased from 30 to 36 in. This was due mainly to a reduction in the number of green tubers; total yields were usually slightly lower from the wider rows.

In 1968 and 1969 the work was extended to compare 30 in. with 36 in. rows on large plots of 2 – 3 acres, the principal object being to assess the extent to which the improvement in work rate, theoretically possible on the wider rows, could be achieved in practice. The two years presented two very different sets of conditions. In 1968 a dry spring was followed by an exceptionally wet summer and autumn, while in 1969 a difficult spring gave way to fine, dry weather from June onwards. In both years improved rates of harvesting were recorded on 36 in. compared with 30 in. rows, using the same single-row harvester (suitably adjusted) for both row widths. The improvement in work rate was just over 20 per cent in 1968 and 35 per cent in 1969. These figures may be compared with the improvement of 16.7 per cent which might be expected on theoretical grounds. In 1968 the forward speed of the harvester was the same on both row widths and in 1969 a faster speed was possible on the wider rows because there were fewer clods to be separated from the potatoes. The ridges on 36 in. rows contained fewer clods because with the greater area between the rows it was not necessary to work so deeply to make enough tilth to build the ridges. In contrast, on 30 in. rows deeper inter-row cultivations were needed; these brought un-weathered soil to the surface and this subsequently dried to clods in the ridge.

Although the advantages of wide rows have been clearly demonstrated, certain problems remain to be overcome before the widespread adoption of an increased row width can be generally recommended. The first problem is that much of the machinery used in the potato crop in this country cannot be easily adapted for use on 36 in. rows. The second concerns the integration of this row width into a farming system which includes other row crops. At present these difficulties can best be overcome in the light of the circumstances on a particular farm rather than by generalizations.

COMMERCIAL ASSESSMENT OF NEW POTATO VARIETIES

J. B. Smith, *Arthur Rickwood Experimental Husbandry Farm*

Much useful information on agronomic, disease resistance and field characteristics of new potato varieties can be obtained from trials in the N.I.A.B. programme. These small plot trials, however, do not give information on the likely behaviour of a new variety under the rough and tumble commercial conditions of mechanical planting, harvesting and bulk storage. Usually the first indications on this scale are when commercial producers themselves begin to grow small acreages of new varieties after their release.

The Potato Marketing Board is now promoting a scheme whereby this type of information can be obtained at an early stage in the development of the variety. New varieties selected on the basis of their field performance in N.I.A.B. trials are now to be grown on a commercial scale alongside one another with standard varieties as controls at a number of geographically diverse centres. Experimental Husbandry Farms, Agricultural Colleges, Farm Institutes and the Norfolk Agricultural Station are co-operating with the Potato Marketing Board in this venture.

Produce from these 'commercial' plots in the second year will then be assessed by experimental staff at the Potato Marketing Board station at Sutton Bridge before and after the bulk storage period. Records will be kept of weight loss in store and the contribution sprouting makes to this loss, damage and disease assessment and quality tests. The latter will include dry matter and reducing sugar contents, disintegration and blackening on cooking.

Each co-operating centre will grow varieties relevant to their district; for example at the Arthur Rickwood Experimental Husbandry Farm those new maincrop varieties with blight or eelworm resistant characteristics are particularly relevant. In 1969 at that E.H.F. half a ton of once grown seed from each of the eight varieties Pentland Crown, Pentland Dell, Pentland Hawk, Pentland Ivory, Ulster Concord, Désirée, Majestic and King Edward have been grown from Foundation Stock seed using intensive aphid spraying and early haulm destruction and lifting. Some ware crops of Maris Peer, Maris Piper and King Edward were also grown and are currently being stored and assessed by the Potato Marketing Board according to the scheme outlined above.

This will result in assessments of all aspects of quality according to the precisely determined standards used by the Potato Marketing Board at its experimental station at Sutton Bridge.

SHORT TERM SHELTER FOR ARABLE CROPS

J. L. Short, *Gleadthorpe Experimental Husbandry Farm*

High winds and dry soil conditions can produce serious wind erosion in sugar beet seedbeds, often with disastrous results for the crop. In severe cases the topsoil and the beet seed may be completely carried away or young plants may be cut down by the sand-blasting effect of flying soil particles. Most damage from wind erosion occurs in the eastern half of the country, particularly on black fen soils and on sands. On peaty soils the crop is most susceptible to damage in the seedbed before the crop or the weeds have germinated. On sand land the greatest risk is to the newly emerged crop, either by bombardment with abrasive particles or by strangles induced by the stem rubbing on the edge of the soil crust. Although the soil at Gleadthorpe E.H.F. very rarely blows, the farm is situated on a coarse sand soil and close to areas which do suffer wind erosion. Some experimental work to develop suitable control measures is therefore being undertaken; similar trials are being carried out on fen soils at the Arthur Rickwood E.H.F.

The method adopted at both farms aims at the reduction of wind speeds at the soil surface by the use of nurse crops, which have the additional advantage of binding the soil by their root systems. Ideally, the nurse crop should afford protection throughout the danger period, that is, from the time the sugar beet is drilled until it has at least eight true leaves. During the latter part of this period it should not compete with the crop.

At the Arthur Rickwood E.H.F. two trials were carried out in 1969, on onions and on sugar beet. A prostrate barley variety (Deba Abed) or mustard was drilled between the crop rows at the same time as the crop was sown, whilst a third treatment allowed naturally occurring weeds to grow between the crop rows. The rows of both crops were band sprayed to control weeds. The guard crop was destroyed at three stages: early, before competition could occur; when the onions were in the two-leaf, or sugar beet in the 6 to 8 leaf, stage; or late, when competition between the guard and crop plants had started. Mechanical destruction with hoes or rotovator was compared with the use of a paraquat / diquat mixture applied by dribble-bar. The trial at Gleadthorpe E.H.F. was conducted only on sugar beet, which was drilled in either March or April. The guard crop of barley (either a prostrate or an erect variety) was drilled or broadcast at six dates, starting as early in the season as possible. The beet was band sprayed with a protham/endothal mixture to kill the broadcast guard crop falling within the row of beet. Inter-row guard crop destruction was by paraquat applied by a vibrating jet sprayer.

Experience in 1968 and 1969 at Gleadthorpe showed that even when the shelter cereal was drilled in late February it provided no effective protection until mid-April; natural weeds were about a fortnight later in producing a useful cover. The guard crop afforded reasonable protection until mid-May when it rapidly grew to the point where competition with the guarded crop was becoming serious and a quick kill of the guard crop became essential. Later drilling of the guard crop made a difference of only a few days in the time when it had to be destroyed. After destruction of the shelter it was estimated that the trash remaining afforded some protection for a further fortnight before rotting away.

Where the beet was drilled after the shelter crop, but before the latter had emerged, great care in marking out was necessary to avoid superimposing the rows. It was also apparent that drilling sugar beet into the stale seedbed prepared for the shelter crop was not always satisfactory due to poor germination.

At Arthur Rickwood E.H.F. mustard had grown 12 in. high and the barley into rosettes 12 in. in diameter by 27 May and some difficulty was experienced in killing them. At Gleadthorpe E.H.F. band spraying with protham/endothal failed to control broadcast barley. At both farms paraquat was effective in killing the shelter crop, but there was a tendency for the spray material to flick off the shelter leaves on to the crop as the sprayer guards passed through.

Erosion control by living shelter seems sufficiently promising for work to continue at both farms in 1970. Some changes in technique may be adopted as a result of experience in 1969. If a prostrate barley is used again a single row between crop rows should be sufficient, but an erect variety may be preferred, because it is less likely to spread into the crop rows. The brown mustard (var. Trowse) used in 1969 may be replaced by *Sinapis nigra*, which is likely to be a less aggressive competitor with the crop.

SOIL AMELIORATION WITH P.F.A.

W. A. Walker, *Gleadthorpe Experimental Husbandry Farm*

Sands have an inherently low water-holding capacity and anything that can be done to improve this should raise crop yields. Much of the soil at Gleadthorpe Experimental Husbandry Farm contains a high proportion of coarse sand (60 per cent) and relatively little fine sand and silt (28 per cent). Work at the National Vegetable Research Station has shown that the water holding capacity of soils is closely related to the proportion of fine sand and silt they contain.

Pulverized fuel ash (P.F.A.) is produced from the combustion of finely ground coal at electricity generating stations and has a particle size similar to silt and fine sand, so this material might be expected to increase the water-holding capacity of coarse textured soils if it is supplied in sufficient quantities.

P.F.A. is highly alkaline and, depending on coal source, contains high levels of minor elements some of which can be toxic to plant growth.

In early 1968 a trial was started at Gleadthorpe E.H.F. to study the effects of applications of both P.F.A. and marl on crop yields. Rates of ash and marl equivalent to 0, 150 and 300 tons per acre were mixed into the top 6 in. of soil on separate areas of land. Both materials were spread evenly on ploughed land during the winter months and incorporated into the soil by rotovation to obtain a good mix.

In the first year barley was planted, but the crop was killed by boron toxicity on the ash plots. Reasonable and similar crop yields were obtained from the marl and control plots.

In 1969 sugar beet was grown and, from observation, the plants on the

ash treated plots looked stronger and more vigorous at emergence, and this tendency was apparent throughout the season compared with the plants on the marl and non-treated areas. There was a slightly higher yield of clean beet where ash had been applied.

On the evidence of this trial the high boron content of the pulverized fuel ash makes impractical the single application of 300 tons or so per acre which would be needed to give a significant boost to the moisture holding capacity of coarse textured sands. A further trial was therefore designed to test what rates could safely be applied to land to be cropped initially with sugar beet, which is one of the more tolerant crops to high boron concentrations. Ash was applied at rates equivalent to 0, 50 and 100 tons per acre. These quantities were either ploughed in or applied to land after ploughing and the whole area cultivated with a tined implement to eliminate wheelings and give a partial mix.

Sugar beet was drilled in 1969. There were no differences in plant emergence counts and a satisfactory crop was grown following all rates of application.

This trial on pulverized fuel ash will receive further dressings each time sugar beet is grown until the total application on each plot has reached the target level of 300 tons of ash per acre. The plots on both trials will be cropped with a typical rotation manured as normal and records of crop yields will be taken to measure the long term effects of the treatments.

THE PHASING OUT OF CERTAIN LONG-TERM EXPERIMENTS

R. D. Russell, *Regional Soil Scientist, N.A.A.S. South West Region.*

The Ley Fertility, Residual Phosphate and Residual Potash experiments were started on certain Experimental Husbandry Farms in the early 1950's and are now in process of being wound up. Early results from the phosphate experiment were reported by Patterson and Williams* and the potash experiments were reported by Clark and Smith†.

Details of the sites are as follows:

Farm	County	pH (water)	Soil Series	Soil description	Annual rainfall (mm)
Boxworth	Cambridge	7.4	Hanslope	Silty clay loam on chalky boulder clay over Ampthill or Kimmeridge clay.	599
Bridget's	Hampshire	7.9	Andover	Very fine sandy loam on chalk with some flints	762
Gleadthorpe	Nottingham	6.7	Newport	Loamy sands with stones derived from Bunter Sandstone overlying Bunter Pebble beds.	635
High Mowthorpe	Yorkshire	7.7	Andover	Silty loam with chalk and flints over chalk.	762
Rosemaund	Hereford	5.9	Bromyard	Silty loam to silty clay loam on Old Red Sandstone.	686
Trawscoed	Cardigan	5.5	Teifi	Silty loams on Silurian shales.	1168

Each experiment is being conducted at each of the sites, except there is no potash experiment at Rosemaund.

The Ley Fertility experiment comprises four 6-year rotations and one 12 year one. Comparisons are made between the types of crops grown during the first three years of the 6 year rotations and the first nine years of the 12 year rotation (the 'treatment sequences'). The last three years of all five rotations are cropped in the same way, (the 'testing sequence'), allowing

* Experimental Husbandry 8 (1962) pp. 85-103.

† Experimental Husbandry 12 (1965) pp. 15-23.

the residual effects of the treatment sequences to be measured in terms of crop yields, soil analysis, etc. The experiment has been modified slightly on several occasions but the current layout allows a four level nitrogen test on each crop in the testing sequence. The main treatments are:

Treatment sequences:

6 Year Rotations

Arable: Sugar beet, kale or mangolds; spring oats; 1-year clover or Italian ryegrass ley with all produce cut and removed.

3-year grass/clover ley with all produce cut and removed, receiving up to 240 units of nitrogen per year.

3-year grass/clover ley grazed only, receiving up to 240 units of nitrogen per year.

3-year grass/clover ley grazed only, receiving up to 120 units of nitrogen per year.

12 Year Rotation

9-year grass/clover ley grazed only, receiving up to 120 units of nitrogen per year.

Testing sequences: the last three years of all the above rotations consist of winter wheat, potatoes and spring barley.

In the Residual Phosphate experiment, four types of fertilizer were used.

Superphosphate (18 or 21 per cent P_2O_5)

Gafsa ground mineral phosphate (29 per cent P_2O_5)

Bessemer basic slag (16–18 per cent P_2O_5)

Powdered dicalcium phosphate dihydrate (39 per cent P_2O_5)

These phosphorus carriers, and potassium chloride in the Residual Potash experiment, were applied in different ways, either annually or in equivalent amounts triennially, and at different rates. Treatments have now been suspended pending a final assessment in 1973 and 1974. In the meantime the plots are undergoing a period of uniform cropping without the application of potash or phosphate as the case may be.

The start of the Ley Fertility experiment was phased over three years. The last of the treatment sequences on the 6-year rotations commenced in 1969, so the experiment will conclude after the last testing crop on that sequence is harvested in 1975.

Thus there are in existence at present five or six soil types, each with known histories of cropping and manuring going back seventeen years or more. If any person would like samples of the soils from any of these experiments for laboratory or even pot work it may be possible to make these available. Anyone interested should contact the Chairman, N.A.A.S. Soil Scientists' Field Experiments Committee, c/o Ministry of Agriculture, Fisheries and Food, Great Westminster House, Horseferry Road, London, S.W.1.

Grassland and Forage Conservation

PATTERNS OF NITROGEN APPLICATION TO GRASSLAND

R. W. Clare, *Boxworth Experimental Husbandry Farm*

The seasonal differences inherent in grass growth rate lead to a characteristic peak of production in the early part of the season, although it is possible to influence this seasonal pattern by varying the time of nitrogen applications. The response of a grass sward to nitrogen varies over the season, being greatest in spring and declining during summer, especially under drought conditions.

Intensification of livestock production systems on grassland has resulted in a demand for more even seasonal distribution of herbage. As intensification has increased so has the use of nitrogen fertilizer so that 300-400 units per acre are now common. At this level of input the cost of nitrogen fertilizer becomes a significant factor in the cost of meat or milk from grass.

Considerable interest was aroused by reports of experiments in America and on the continent which showed that anhydrous ammonia injected into the soil supplied nitrogen over a longer period than solid forms of nitrogen fertilizer. If this result could be repeated under British climatic conditions a more even supply of nitrogen and grass growth should result from a single early spring application of this material.

Other factors such as frequency of defoliation, soil and climatic conditions also influence the response of grass to fertilizer nitrogen. This is a complex situation. The problem is in deciding when to apply nitrogen and in what quantity, and a number of experiments are being conducted at E.H.Fs. in an attempt to provide information on which to base practical solutions.

E. H. F. EXPERIMENTS

Anhydrous ammonia has been compared with solid nitrogen fertilizers at several E.H.Fs. covering a wide range of soil types and climatic conditions. A single large spring application of anhydrous ammonia was found to be no more effective than a similar application of solid nitrogen fertilizer. Both accentuated the spring peak of herbage production but had little effect on promoting mid-season growth. A more even seasonal production and a greater total yield of grass resulted from small but regular applications of solid nitrogen fertilizer. Similar responses were obtained by further injections of anhydrous ammonia in mid-season, but injection at this time can often be difficult if ground conditions are dry and hard. The unit cost of anhydrous ammonia is lower than solid nitrogen fertilizer; application costs are higher but these decrease as the rate applied per acre increases.

Other experiments using solid nitrogen fertilizer are being conducted to examine the effect of different patterns of application on the seasonal growth of grass.

At Rosemaund two methods of applying 160 units nitrogen per acre were compared and the yields obtained from four silage cuts. The treatments were:

Bulk — 160 units as a single application during March.

Split — 40 units during March and 40 units after each of the first three cuts.

The soil type at Rosemaund is a silty clay loam of the Bromyard series and the pasture was a five year old ryegrass/white clover ley.

Yields of dry matter (cwt per acre)

1966	28 April	14 June	29 July	15 Sept.	Total
160 units N	11.2	47.8	7.7	5.1	71.7
4 × 40 units N	5.5	47.9	15.5	22.8	91.7
1967	28 April	14 June	28 July	18 Sept.	
160 units N	16.7	50.6	3.1	1.7	72.1
4 × 40 units N	5.5	49.2	10.7	4.5	69.9
1968	2 May	14 June	30 July	13 Sept.	
160 units N	25.0	30.5	8.3	3.7	67.5
4 × 40 units N	16.6	35.9	13.7	8.4	74.7

The single dressing of 160 units applied in mid March accentuated the natural seasonal pattern of grass growth. In each year a greater yield was obtained at the first cut but much lower yields were obtained at the third and fourth silage cuts. Splitting the nitrogen applications into four equal dressings provided a more even seasonal production of herbage and a greater total yield two years out of three.

At Drayton E.H.F. the effects of high rates of nitrogen applied at different times within the growing season have been examined in order to obtain maximum production from grass harvested in four silage cuts. The soil type at Drayton is calcareous clay and the sward was a three year old S24 ryegrass ley.

The treatments were as follows:

1. Nitrogen rates: 240, 360 and 480 units per acre
2. Pattern of application:

	Early	1st cut	After 2nd cut	3rd cut
P ₁	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	0
P ₂	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
P ₃	$\frac{1}{2}$	$\frac{1}{2}$	0	0

3. Types of nitrogen: sulphate of ammonia, ammonium nitrate/lime

The 'early' applications of each treatment were carried out in the third week of April while subsequent applications varied with the time of taking the silage cuts. All plots received a basal dressing of 200 units P_2O_5 in early April each of year.

*Effect of three patterns of nitrogen application at each of four dates of cutting (cwt D.M. per acre)
(mean of three nitrogen levels and two types of fertilizer)*

1968	Date of harvesting				Mean
	28 May	17 July	5 Sept.	30 Oct.	
P_1	38.1	42.1	21.1	9.7	111.0
P_2	38.6	42.0	22.5	15.1	118.2
P_3	38.2	47.3	12.4	7.4	105.3
1969	6 June	18 July	5 Sept.	2 Oct.	Mean
P_1	37.4	22.9	25.7	8.5	94.5
P_2	28.7	23.5	25.3	8.8	86.3
P_3	40.8	24.4	25.4	8.2	98.8

During the exceptionally wet summer of 1968 the most productive pattern of nitrogen application was the 'little and often' treatment (P_2) where the applications were equally divided for the four silage harvests. This was not the case in 1969 which was a much drier summer when the effectiveness of the nitrogen applied to the last three harvests was reduced. Under these conditions the highest total yield was obtained where all the nitrogen had been applied by early June (P_3).

During 1968 the most even seasonal production of herbage was obtained from equal applications of nitrogen for each silage cut (P_2). Where the nitrogen was all applied for the first two cuts (P_3) the characteristic seasonal production of herbage was emphasized. In 1969, however, different patterns of nitrogen application had little effect on the seasonal production of herbage.

A similar experiment was started at Trawscoed E.H.F. in 1969, the results of which are not yet available. The soil type is a silty loam over Silurian shales; the rainfall is also much higher, averaging 45 inches per annum.

THE INFLUENCE OF THE GRAZING ANIMAL

The grazing animal introduces new factors which modify the pattern of grass growth and fertilizer response. Selection of the more digestible portion of the sward results in defoliation of tillers to different heights. The degree to which selection takes place depends on the quantity of herbage available per animal. Treading may cause soil compaction but during wet conditions 'poaching' can result, especially on the heavier soils. Faeces and urine are

dropped onto the sward causing fouling but also allowing nitrogen to be recirculated. Parasitic worm burdens can build up at grass and limit animal performance.

At Boxworth during 1966 and 1967 the same nitrogen treatments were compared as at Rosemaund but using a permanent pasture under paddock grazing conditions. The results demonstrated similar trends to those obtained at Rosemaund. A single application of 160 units nitrogen applied in mid-March accentuated the early seasonal peak of herbage production and also its subsequent decline during the drier summer months. Where the 160 units of nitrogen was applied in four applications of 40 units per acre a more even seasonal distribution of herbage was obtained, and also in both years a higher total yield.

In 1968 and 1969 the level of nitrogen was increased to 300 units per acre. The patterns of nitrogen application were.:

Bulk — 150 units in March with a further 150 units per acre after the second grazing.
Split — 75 units in March with 45 units per acre after each of the first five grazings.

Herbage dry matter on offer (cwt per acre)

1968			1969		
Grazing periods	Split	Bulk	Grazing periods	Split	Bulk
9 Apr. to 30 Apr.	8.5	8.5	5 May to 22 May	13.9	16.1
30 Apr. to 23 May	16.9	16.6	22 May to 17 Jun.	18.5	20.6
23 May to 10 Jun.	14.2	13.5	17 June to 10 Jul.	16.7	17.1
10 Jun. to 2 Jul.	14.7	11.7	10 Jul. to 31 Jul.	11.0	12.2
2 Jul. to 28 Jul.	15.1	13.5	31 Jul. to 13 Aug.	6.1	5.8
28 Jul. to 25 Aug.	15.5	16.2	25 Aug. to 14 Sep.	9.9	8.4
Total	84.9	80.0	Total	76.1	80.2

During 1968 abnormally high rainfall was experienced over the period June to September inclusive; 14 inches were recorded compared with the average of 8 inches. Under these conditions the seasonality of herbage production was not so apparent. There was nevertheless a tendency for greater mid-season growth and a higher total yield to be produced following the more evenly spread application of nitrogen.

1969 was a much drier summer with little grass growth during late July and early August. A greater total yield was obtained where all the nitrogen had been applied by the third week in June. Again a more even seasonal production of herbage resulted from small regular applications of nitrogen throughout the season.

Animal Performance

At Boxworth paddocks receiving the fertilizer treatments were grazed by autumn-born Friesian heifer calves at a stocking rate of 3.77 animals per acre. Surplus herbage was removed by conservation in the earlier part of the season resulting in a higher stocking rate during this period. It was possible to use only one level of stocking, so the interaction of animal performance and stocking rate cannot be evaluated.

Seasonal trends in animal performance closely followed those of herbage on offer. Where large infrequent dressings of nitrogen were used animal performance was markedly seasonal in nature, while regular small nitrogen applications gave a more even performance over the season. The total liveweight gain over the whole season showed no real difference between the two methods of nitrogen manuring.

Animal Health

At Drayton the experimental site was on the Evesham series derived from the Lower Lias Clay which is known to give rise to grass high in molybdenum (teart pasture) in Somerset. It was thought that heavy dressings of nitrogen might encourage a higher molybdenum content in the herbage, but chemical analysis showed that the level of molybdenum in the herbage was not affected by nitrogen fertilizer treatment.

It is known that high levels of nitrate-containing fertilizer increase the nitrate nitrogen content of herbage, and that nitrate is reduced in the rumen to nitrite which can be toxic. After heavy applications of nitrogen up to 0.4 per cent $\text{NO}_3\text{-N}$ in the herbage dry matter has been found at Boxworth but veterinary tests have failed to detect signs of toxicity in the animals.

DISCUSSION AND SUMMARY

Herbage from this experiment was analysed and its nutritive value assessed. Information on the nitrogen content of herbage was required to allow the rate of nitrogen uptake and removal to be assessed. If infrequent large dressings of nitrogen are to be of value then all the nitrogen must not be removed in the first harvest. The uptake of nitrogen by the herbage occurs rapidly after application but there is some delay before the grass responds and growth begins. Uptake also increases with the amount of nitrogen fertilizer applied. The present series of experiments confirmed this, since heavy infrequent nitrogen applications resulted in a greater offtake of nitrogen in the herbage at the first subsequent harvest. The residual value of such heavy nitrogen dressings is therefore likely to be disappointing.

Garwood and Williams at the Grassland Research Institute showed that grass growth was depressed when all the water available to plants in the surface soil horizon was exhausted. They demonstrated that water extraction continued from lower soil horizons, down to a depth of at least 3 ft. Plant nutrients, particularly nitrogen, are concentrated near the soil surface under grass and are unavailable when this zone is dry. In these experiments, if nutrients were injected into the lower soil horizons a response was observed. They concluded that the depression in growth could be attributed more to the poor availability of plant nutrients rather than to a lack of water. The results of the experiments described in this article fit their conclusions in that normally regular small nitrogen dressings proved superior. In the drier years, however, this was not so apparent indicating that fresh nitrogen dressings were not always readily available to the sward.

The whole subject of nitrogen manuring of grassland has recently been reviewed by a joint N.A.A.S. and A.R.C. committee, and proposals have been made to study various nitrogen levels and patterns of application spread over the season. These experiments will cover a wider range of soil type and climatic conditions than it has been possible to investigate to date.

MIXED AND ALTERNATE GRAZING

J. MacLeod, *Rosemaund Experimental Husbandry Farm*

Many cattle graziers would feel that the introduction of sheep to their grazing systems would result in a poorer performance from the cattle but the widespread practice of mixed grazing underlines the feeling that mixed or alternate grazing increases the efficiency of grass utilization and the total meat production per acre. The three alternatives in mixed stocking are:

Adding beef cattle to a sheep enterprise;

Adding sheep to a beef enterprise;

Substituting beef and sheep to maintain a constant stocking rate per acre.

Of these three approaches the last two have received most attention on the Experimental Husbandry Farms and the scope of this review is confined to them.

From 1957 to 1961 a co-ordinated trial was conducted at Drayton, Rosemaund and Trawscoed on the mixed stocking of pasture. This was a cattle system with sheep added and the object was to see if the sheep had a detrimental effect on the cattle gain, and if this was the case whether the extra production from sheep would compensate for it.

Stocking rates per acre

Treatment	Drayton		Trawscoed and Rosemaund	
	Cattle	Sheep	Cattle	Sheep
Low cattle	0.9	—	1.1	—
Low cattle and low sheep	0.9	0.9	1.1	1.1
Low cattle and high sheep	0.9	1.5	1.1	1.6
High cattle	1.5	—	1.6	—
High cattle and low sheep	1.5	0.9	1.6	1.1
High cattle and high sheep	1.5	1.5	1.6	1.6

The use of nitrogen at 36 units per acre at Rosemaund and Drayton and 48 units per acre per annum at Trawscoed looks modest in terms of today's practice but was matched to the stocking rates. The cattle at Rosemaund and Drayton were yearlings at turnout in April and remained on the plots until late September or early October. At Trawscoed the cattle were 18 months old at turnout in April and remained at grass until early September. The ewes with their twin lambs were put on to the plots in March or April and the lambs sold as they became fat. The lambs were generally all sold fat by mid-July and at that point the ewes were taken off the paddocks so that all six treatments were grazed by cattle alone from mid-July to the end of the grazing season.

The conclusions from the experiment were that the highest liveweight gain per acre came from the highest stocking rate. The lambs put on weight

and went fat at all centres irrespective of the presence of cattle. While the individual liveweight gain of the cattle declined with increased stocking rate the total production per acre increased. The presence of sheep depressed the performance of cattle when they grazed together and at Rosemaund and Drayton this effect continued after the sheep were removed. At Trawscoed, following the removal of the sheep in mid-July, the cattle recovered from the effects of competition by the sheep, particularly where the high level of sheep stocking had been used. On this treatment the high rate of mixed stocking in the first half of the season prevented the pasture going to head, so that the cattle were left with more highly digestible grazing in the second half of the season. It was observed at Drayton, where the cattle were not finished at pasture, that the lower liveweight gain per head on the higher stocking rates lead to a disproportionately long finishing period in winter with this class of stock.

During the 1960's the trend to intensification and a corresponding increase in the use of nitrogen has required further investigation of grazing systems. Trawscoed has concentrated on the potential complementary effect of mixed stocking where sheep have been substituted for cattle in a 3 : 1 ratio and has investigated the liveweight gains per head and per acre as compared with monoculture of beef or sheep. Drayton has investigated the effect of increasing stocking rates under a mixed grazing system with sheep and cattle in a 3 : 1 ratio. At High Mowthorpe and Rosemaund sheep have been added to intensive beef systems in an attempt to improve the grass utilization and increase the output per acre. Work on pasture utilization at Rosemaund has suggested that under intensive grazing by beef cattle alone there could be rejection of up to 40 per cent of the grass on offer by the end of the season. It was felt that one ewe and her lambs could be introduced for each beef animal to utilize the rejected grass, to extend the productive grazing season and to produce extra liveweight gain without depressing the performance of the cattle.

Work started at Drayton in 1961 to investigate the potential for meat production through a mixed grazing system of grass stocked at various intensities and given different rates of nitrogen. During the first period, as experience was gained on these farm units and the composition of the swards settled to their nitrogen regimes, the stocking rates were gradually increased. From 1964 to 1967 the stocking rates were constant.

Annual stocking rates per acre at Drayton, 1964-67

Nitrogen level units/acre/annum	Yearling bullocks	Breeding ewes
Nil	0.37	1.12
80	0.47	1.40
160	0.56	1.67

Each farm unit occupied 21.5 acres divided into ten paddocks, and conservation was taken as barn hay in May and June. The February born yearlings steers weighing 6 cwt were turned out to the paddocks in the spring, grazed throughout the summer and were finally fattened out of yards in the following autumn or winter on the hay conserved from their plots and 2 lb per head per day of concentrates. The ewes were housed for ten weeks before

lambling and spent the remainder of the year on the paddocks. Lambs were sold fat at 85 lb liveweight or as stores in September.

Mean production from grazing at Drayton, 1964-67

	Nitrogen, units/ac		
	Nil	80	160
D.L.W.G. of cattle (lb)	2.16	2.13	2.01
Production/ac from cattle (lb)	136	166	188
Production/ac from sheep (lb)	154	177	217
Lambing per cent	159	157	161
Total output/ac from cattle and sheep (lb)	290	343	405

Increased levels of stocking rate and nitrogen had little effect on the individual performance of the cattle and the production per acre increased. Although the total output per acre increased substantially the increase when measured in gross margin terms was disappointing. Each 80 unit increment of nitrogen gave a 12 per cent boost in gross margin per acre and it was felt that to gain any substantial improvement the stocking rates would have to be intensified further. In 1968 the stocking rates for the cattle were increased to 0.38, 0.57 and 0.89 animals per acre at nil, 160 and 320 units nitrogen per acre respectively, while the sheep were increased to 1.14, 1.71 and 2.66 per acre to maintain the 1 : 3 ration of cattle to sheep. The cattle were February born yearlings weighing 6 cwt at turnout.

Mean production from grazing at Drayton, 1968 and 1969

	Nitrogen, units/ac		
	Nil	160	320
D.L.W.G. of cattle (lb)	2.29	2.10	1.87
Production/ac from cattle (lb)	158	217	302
Production/ac from sheep (lb)	137	212	299
Lambing per cent	139	165	159
Total output/ac from cattle and sheep (lb)	295	429	601

Although the output per acre increased the individual performance declined, both in terms of the daily liveweight gain of the cattle and in terms of the percentage of lambs sold fat, which fell from 82 per cent to 52 per cent to 23 per cent with increasing stocking rate. The increase in stocking rate from the least intensive to the most intensive produced a 60 per cent increase in the gross margin per acre.

At Trawscoed the monocultures of cattle and sheep were compared with a mixed stocking treatment at the same overall stocking rate on the basis of a 3 : 1 ratio of sheep to cattle.

Stocking rates per acre

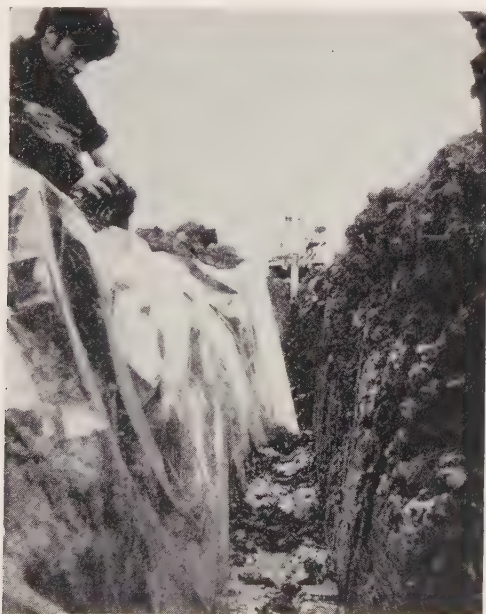
	Cattle	Cattle + Sheep	Sheep
High	3.0 cattle	1.5 cattle + 4.5 ewes	9.0 ewes
Medium	2.5 cattle	1.25 cattle + 3.75 ewes	7.5 ewes



Lessons from a large dairy herd (see page 1)

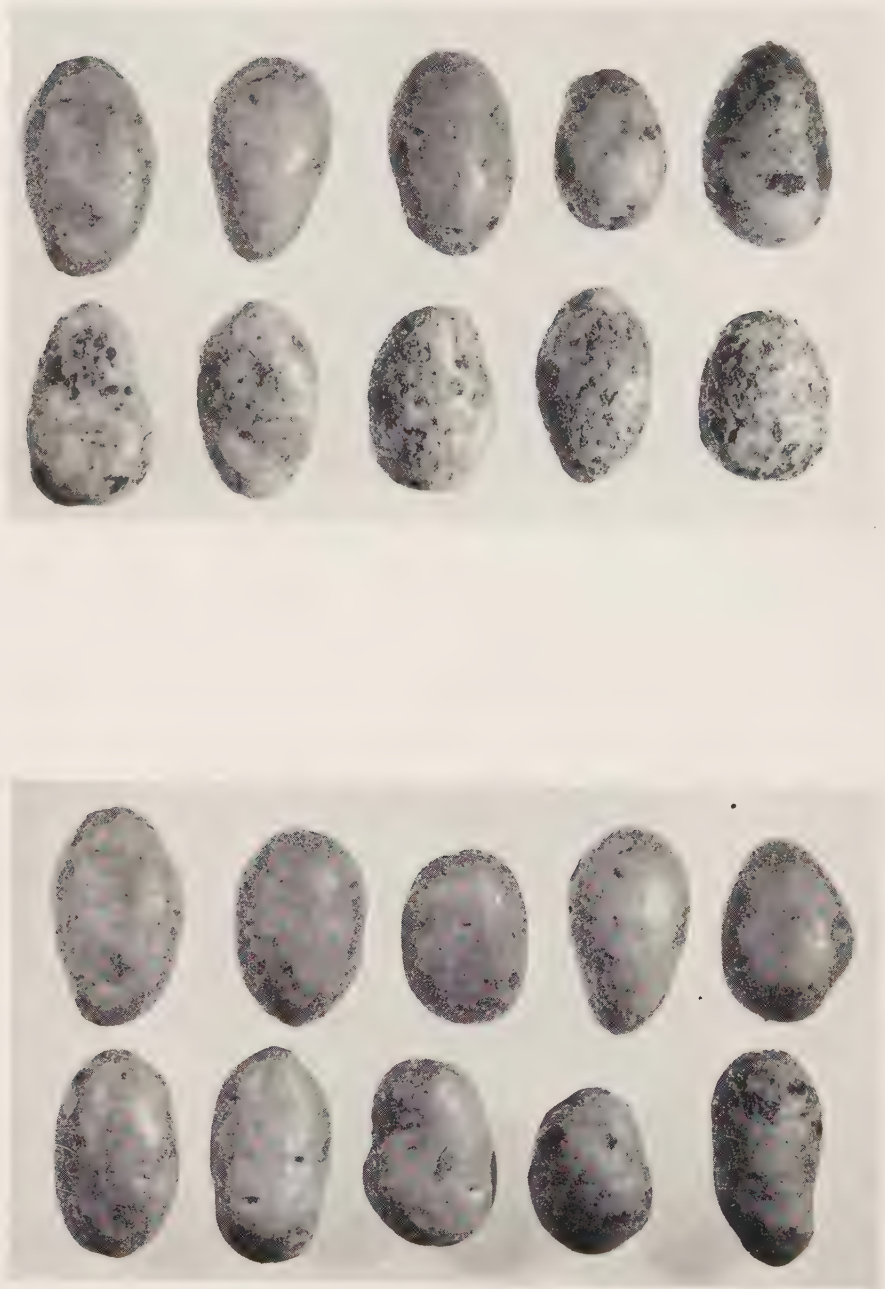
The Bridget's dairy herd on its way to grass, down one of the twin 20 ft wide access roadways. In the background is the parlour, with the cubicle houses and tower silos behind.

DRAYTON EXPERIMENTAL HUSBANDRY FARM



A new drainage experiment (see page 8)

Lining a 4 ft deep trench with polythene to isolate plots on the new drainage experiment.



Irrigation of farm arable crops (see page 31)

Majestic potatoes grown without irrigation (upper) suffered a severe attack of scab, while those that received frequent irrigation (lower) developed relatively little scab.



Short term living shelter for onions (see page 46)

A mustard nurse crop during (upper) and after (lower) desiccation with paraquat.



Calf Housing (see page 91)

Calf house showing inlets and outlets of ventilation ducts on north side, and the Yorkshire boarding on the naturally ventilated compartment at the western end of the house.



Calf house interior showing ventilation control equipment, thermostats and ventilation duct above the calf pens in one of the fully insulated compartments



New glasshouses at Efford

Right, N-S, multispán. Centre, E-W, widespan with Mansard roof. Left, E-W, multispán.

STOCKBRIDGE HOUSE EXPERIMENTAL HORTICULTURE STATION



Self blanching celery

Effect of daylength on rosetting of celery: variety Golden Self Blanching



Brussels sprouts spacing

Smaller sprouts are produced at the closer spacing with less rotting and higher yields.



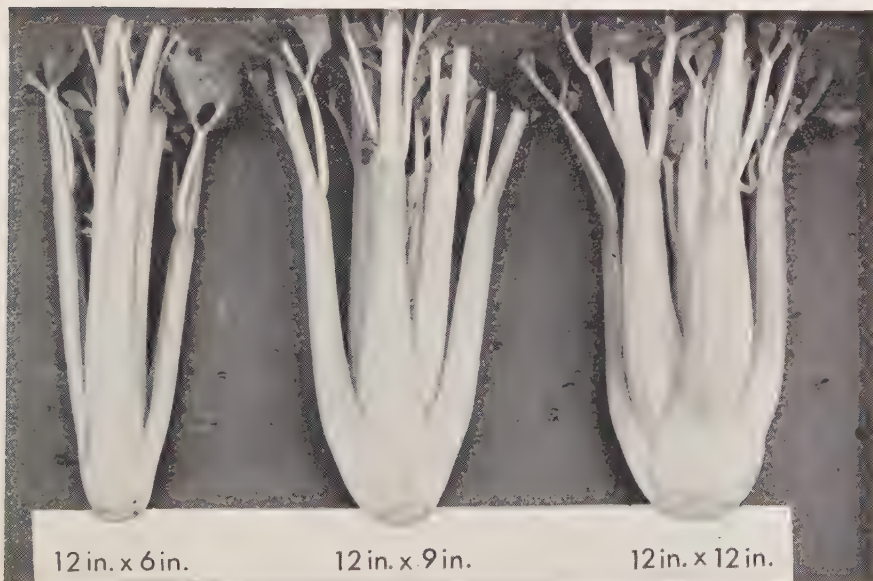
At wide spacings the stalks become bent and difficult to harvest mechanically. Close spacing solves these problems.



Fruit variety trials

Apple Crispin: a cultivar brought to the notice of fruit growers by the National Fruit Trials and now yielding at over 1,000 bushels per acre in commercial orchards.

ARTHUR RICKWOOD EXPERIMENTAL HUSBANDRY FARM



Irrigation and spacing of self-blanching celery

Effect of spacing on grade and petiole length of celery: variety Lathom Blanching.



Narcissus storage treatments for early outdoor flowering

A pre-cooled crop of N. Fortune. Photograph taken on 28 February after the crop had been gathered. Left hand side shows pre-cooled N. Magnificence. Note early senescence compared with untreated bulbs on right hand side.

STOCKBRIDGE HOUSE EXPERIMENTAL HORTICULTURE STATION



Propagation of rhubarb

(Left) Typical leaf bud cuttings

(Right) Crown division

All six treatments received 300 units of nitrogen per acre per annum in 1967 and 1968. In 1969 250 units of nitrogen per acre were applied. The cattle were Hereford x Friesian heifers averaging 500 lb at turnout and the sheep were Welsh Halfbreeds which had been crossed with a Dorset Down ram. The ewes were inwintered then lambed early and turned out into a wood for ten days before going on to their paddocks. Lambs were sold fat at 70 lb liveweight and any left in mid-August sold as stores. The cattle were turned out in April and yarded in October.

*Mean production from grazing at Trawscoed, 1968 and 1969**

Stocking rate/ac	Cattle L.W.G. per head (fasted wt)†	Cattle D.L.W.G./head (fasted wt)†	Total production of beef and lamb
	lb	lb	lb/ac
3.0 cattle	213	1.31	639
1.5 cattle + 4.5 ewes	264	1.68	895
9 ewes	—	—	929
2.5 cattle	253	1.55	631
1.25 cattle + 3.75 ewes	290	1.85	771
7.5 ewes	—	—	752

*In 1967 the lambs weighed 30 lb when they went onto the plots so the results are not strictly comparable but the trends were very similar.

†Liveweight gains calculated from fasted weights are generally lower than those calculated from full weights.

At both stocking rates the performance of the cattle was better under a mixed stocking regime than under monoculture. With a 162 per cent lambing the sheep played an important role in the total output, and the highest production per acre came from 9.0 ewes per acre. The individual performance of the lambs was also better under the mixed stocking systems where at both stocking rates 95 per cent of the lambs were sold fat as against 64 per cent under monoculture.

At High Mowthorpe sheep have been added to a beef system and compared with various stocking rates of beef under monoculture.

- Treatments
1. 1.6 cattle/acre
 2. 2.4 cattle/acre
 3. 1.6 cattle/acre + 2.4 ewes and 4 lambs/acre
 4. 2.4 cattle/acre reduced to 1.6/acre from midseason

All treatments received 310 units of nitrogen per acre per annum. The seven month old Friesian steers weighing 460 lb liveweight were turned out to grass on 8 May and were yarded on 1 October. Two thirds of each of the cattle treatments were shut off for silage at turnout, while only half of the mixed stocking system was reserved for conservation, because the sheep and cattle grazing separate paddocks required a larger proportion of the total

area for grazing during the early part of the season. On the cattle only systems the steers grazed the spring areas until aftermaths were available. On the mixed stocking system the sheep which were turned out on to the plots on 1 May initially preceded the cattle round the paddocks until aftermath was available when the ewes and lambs moved on to them. In mid-July the ewes were held on the spring grazed area while the lambs were allowed to creep on to the aftermaths. The cattle also grazed the aftermaths from early July. By mid-August all the lambs were sold and the ewes were then stocked heavily on the spring grazed area. On treatment 4 (see above) the four heaviest cattle were taken off the plots in mid-July, brought inside and put on to an *ad lib.* barley beef system thus reducing the stocking rate to 1.6 beasts per acre. Supplementary feed was given to all grazing cattle in September.

Production from grazing at High Mowthorpe, 1969

Treatment	Cattle L.W.G./head (fasted wt)	Cattle D.L.W.G./head (fasted wt)	Additional production	Total production per acre
	lb	lb	lb/ac	lb
1. 1.6 cattle/ac	242	1.66	—	387
2. 2.4 cattle/ac	181	1.24	—	434
3. Mixed stocking	221	1.51	193 (lambs)	547
4. *2.4 cattle/ac reducing	233	1.60	101 (cattle removed)	474

*Figures based on those cattle which spent the whole season at grass.

Increased stocking rate with cattle alone depressed the individual performance but increased the total output. Individual liveweight gain was depressed less and output per acre was higher where the additional cattle grazed only during the first half of the season. The introduction of sheep resulted in a small depression in cattle performance although the lamb production more than compensated for this.

At Rosemaund sheep have been added to a beef system and compared with monoculture of beef. The object was to introduce sheep at a level which would not materially affect the performance of the beef cattle but would improve the grass utilization and output. It was also felt that an integrated system of beef and sheep could be used to control parasites by allocating separate areas to cattle and sheep in the spring and then changing them over in mid-season. All three systems were expected to be self sufficient and to produce enough conservation to fatten the cattle in the winter.

In 1969 150 units of nitrogen were used on all treatments.

- Treatments
1. 2.0 cattle/acre
 2. 2.0 cattle/acre and 2.0 ewes/acre with sheep following the cattle as scavengers.
 3. 2.0 cattle/acre and 2.0 ewes/acre with each class of stock allocated a separate area in the spring and changed over in mid-season.

On treatment 1 the eight month old steers weighing 480 lb were turned out in late April and remained at grass rotationally grazing their ten paddocks until late October. On treatment 2 the inwintered Welsh Halfbred ewes lambed in March to a Dorset Down ram and were turned out on to their ten paddocks with 1.8 lambs per ewe at foot. The cattle were turned out in late April and grazed the paddock ahead of the sheep through the season until yarding in mid-October. The lambs were sold fat throughout the season with 91 per cent going fat by September when the remainder were sold as stores. The ewes stayed on the paddocks until 8 weeks before lambing when they were housed. On treatment 3 the ewes and their lambs were turned out onto 6 paddocks in March. Conservation was taken from this area. The cattle were turned out onto the remaining four paddocks. In early July the sheep moved onto the paddocks the cattle had grazed and the cattle onto the sheep area. Unfortunately this treatment suffered from the less flexible management imposed by the separation of the areas and the resulting higher stocking density. The very wet May caused severe poaching on the cattle plots and then the subsequent drought restricted their recovery so that production was limited, and any benefit from parasite control was overridden by climatic and managerial conditions.

Production from grass at Rosemaund, 1969

	1. Cattle	2. Cattle with sheep following	3. Cattle with sheep changed over
L.W.G./head of cattle (fasted wt)	267	246	196
D.L.W.G./head of cattle (fasted wt)	1.46	1.45	1.37
Days at grass	183	170	143
Beef production / ac (lb)	534	492	392
Lamb sold/ac (lb)	—	276	275
Conservation/ac (tons D.M.)	0.99	0.69	0.59
Total production/ac (lb)	534	768	667

The performance of the cattle on treatment 2 did not suffer in terms of daily liveweight gain but the grazing season was curtailed by 13 days and less silage was made than on treatment 1. However the sheep made a valuable contribution in terms of output per acre which can be set against these other shortages.

In conclusion, the investigation into mixed stocking systems on the E.H.Fs. has shown that sheep can make a valuable contribution to the output per acre from grass without necessarily depressing the performance of cattle. At High Mowthorpe and Rosemaund the results so far are confined to the grazing season but this winter and the next year or two will allow the impact of mixed stocking to be assessed on a year round basis.

PROBLEMS OF PASTURE CONTAMINATION AND HERBAGE REJECTION UNDER INTENSIVE GRAZING

B. Bastiman, *Great House Experimental Husbandry Farm*

The intensification of grazing systems, made possible by improved grassland management and high fertilizer use, has high-lighted the problem of herbage rejection, since it is only under intensive conditions that rejection becomes a major problem.

In order to assess the causes and significance of this problem, and to find possible methods of overcoming it, investigational work has been carried out at Rosemaund, Trawscoed and Great House Experimental Husbandry Farms over the past three years. In general these investigations have been made within the framework of experiments primarily designed to look at the effects of such factors as fertilizer use, stocking rate and grassland management on output per acre.

At Rosemaund the investigations into pasture contamination and rejection have been carried out on intensive paddock systems set up for the 'Nitrogen for Beef' trial. Those at Trawscoed have been carried out within a farmlet comparison of different systems of summer milk production, and those at Great House within a paddock system set up to investigate the problems of intensive, all-year-round milk production in a high rainfall area. One important factor is, however, common to all three centres. This is that the work is being done within the framework of complete rotational grazing systems. Preliminary trials at Great House showed this to be essential, since work not involving a complete system led to exaggerated levels of rejection by animals not accustomed to intensive paddock grazing.

The differences in enterprises between the three centres, together with obvious geographical differences, have led to different approaches to management. In addition, techniques employed at the three centres to assess contamination and rejection have differed. At Rosemaund a grid technique has been employed to assess both contamination and rejection, and results are expressed in terms of percentage areas. At Trawscoed a point quadrat technique has been used to assess rejection only, and at Great House a grid technique has been used to assess contamination, while pre- and post-grazing cuts have been taken to determine rejection in terms of percentage herbage dry matter.

As yet insufficient basic work has been carried out anywhere to determine which of these techniques is best, and all have their limitations. It is not the object of this article to compare techniques, but it must be stressed that, with differences between centres in terms of enterprises, management, geography and methods of assessment it is often difficult to interpret the results obtained at one centre in terms of those obtained at another. Despite this qualification it is possible to assess certain trends, the more important of which are given below.

HERBAGE CONTAMINATION

At Rosemaund set areas within selected paddocks were divided into 2 ft squares, and these grids were examined after each grazing. Squares were classified as contaminated or not according to the presence or absence of muck, either fresh or from previous grazings. On this basis contamination was worked out in terms of percentage of the total area. The results for the first six grazings in 1968 are given in Table 1. The figures given are means of nine treatments involving different nitrogen levels and stocking rates.

TABLE 1

Build-up in contamination (per cent) over six grazings

	Grazing number					
	1	2	3	4	5	6
Percentage contamination	14	33	41	47	50	53

There was a rapid increase in contamination up to the third grazing. Subsequently the rate of increase slowed down as, at later grazings, the addition of fresh muck was counter-balanced by the breakdown of muck deposited at early grazings. A more detailed examination of the data showed that, as would be expected, the level of contamination tended to increase as stocking rates increased.

Since the basic unit of measurement was four square feet these estimates of contamination are high since they assume that, irrespective of its size or position within a square, one muck pat would contaminate four square feet.

At Great House, within selected paddocks, small set areas, each 4 ft x 12 ft, were mapped after each grazing, and the areas of fresh and old muck pats were assessed. The results obtained were similar to those obtained at Rosemaund in that contamination tended to increase up to the third grazing. The absolute levels of contamination were much lower, however, since the area of contamination was regarded as the area of the muck pats themselves, and on this basis it rarely exceeded 10 per cent. This is obviously an underestimate since it assumes that the surrounding grass was not contaminated at all.

No work on contamination was carried out at Trawscoed.

HERBAGE REJECTION

Work at Great House and Trawscoed showed that herbage rejection by the dairy cows grazing the paddocks increased in a fashion similar to that already demonstrated for contamination. These results are given in Table 2, for different paddocks on each farm. The results cover the first three or four grazings only, after which the paddocks were topped.

The data from Great House were obtained from 10 random pre- and post-grazing cuts per paddock taken with an auto-scythe. Each cut was 10 ft x 3 ft.

At Trawscoed the data were obtained using a fixed point quadrat with points at intervals of one foot. The percentage rejection was calculated from the proportion of points which fell on ungrazed herbage.

TABLE 2
Build-up in per cent herbage rejection

Grazing number	Great House			Trawscoed	
	(a)	(b)	(c)	(a)	(b)
1	Nil	Nil	Nil	Nil	Nil
2	25	29	17	5	3
3	52	36	12	6	5
4	—	—	40	13	11

The data from both centres showed a build-up in rejection, but the level of rejection was much lower at Trawscoed. This may have been due to the higher stocking rate on this farm, or due to the fact that some concentrates were being fed to the cows at Great House while none were being fed at Trawscoed. It is not possible to rule out the effect of differences in technique but one of the main criticisms of a cutting technique is that it tends to underestimate rejection.

The situation at Rosemaund, where beef cattle were used, was less clear. In 1967 the increase in contamination over the early grazings was not reflected in an increase in rejection. Rejection even at the first grazing (assessed as percentage area ungrazed, by the grid technique) ranged from 33 per cent to 75 per cent. Over the first three grazings the level of rejection tended to fall at high stocking rates but it increased at low stocking rates. In general, however, the stocking rates and rigid grazing sequence imposed by the 'Nitrogen for Beef' trial made it impossible to utilize the grass efficiently and the levels of rejection early in the season were too high to be practically acceptable.

In 1968 this experiment was modified to allow subjective management, so that animal requirements could be more closely matched to herbage on offer. The levels of rejection for the first four grazings, managed on this basis, are given in Table 3.

TABLE 3
Herbage rejection (per cent) over four grazings

Level of N (units/ac)	Stocking rate (beasts/ac)	Grazing number			
		1	2	3	4
100	1.7	5	11	35	35
	2.5	8	11	27	36
	3.3	11	12	39	29
250	2.5	10	19	23	32
	3.3	19	17	14	49
	4.2	17	17	11	34
300	4.2	10	9	37	54

In general rejection increased up to the fourth grazing when levels approached those obtained at Great House at about the third grazing. It was not possible to follow the pattern of rejection further through the grazing season since paddocks were subsequently topped.

As a result of the subjective management employed there was no apparent effect of stocking rate or nitrogen use on rejection.

In 1968 a trial was carried out at Trawscoed to assess the effects of feeding 4 lb barley per day to cows at grass. Paddocks were not topped prior to the fourth grazing, and the results of this trial in terms of per cent herbage rejection are given in Table 4.

TABLE 4
Effect of concentrate feeding on per cent herbage rejection

Grazing number	Control (unsupplemented)	Supplemented (4 lb barley/day)
1	Nil	Nil
2	5	8
3	6	20
4	13	28
5	17	29

Levels of rejection were much higher on the treatment involving concentrate feeding, since feeding concentrates probably reduced the appetite for herbage dry matter. Thus the level of supplementary feeding is probably an important factor influencing the level and build-up of herbage rejection.

RATE OF BREAKDOWN OF MUCK

This aspect has been studied most closely at Rosemaund where over 2,000 muck pats were identified, when fresh, by means of coloured plastic crystals. From periodic observations the rate of breakdown was obtained. Similar data was obtained at Great House for 106 muck pats which fell on the areas which were mapped to assess contamination.

TABLE 5
Rate of disappearance of muck pats

	Weeks after original recording											
	2	3	4	6	9	12	13	14	16	17	18	20
1. Rosemaund												
Per cent all muck pats still traceable (1968)	96	—	90	79	62	44	—	33	20	—	9	2
Per cent those dropped at first grazing still traceable (1969)	77	—	50	34	18	8	—	3	2	—	2	0
2. Great House												
Per cent all muck pats still traceable	—	73	—	38	13	—	3	—	—	0	—	—
Per cent those dropped at first grazing still traceable	—	81	—	54	26	—	6	—	—	0	—	—

The results from both centres are given in Table 5. The results quoted for all muck pats deposited over a season at Rosemaund refer to 1968 only. The results obtained in 1969 were, however, very similar. The results obtained at Great House refer to both 1968 and 1969, since there were insufficient pats studied to quote the years separately.

The rate of breakdown was much more rapid at Great House than it was at Rosemaund, probably as a result of the differences in rainfall between the two centres. Observations made at both centres indicated that rainfall was an important factor in the breakdown of muck pats.

At Rosemaund the muck pats dropped at the first two grazings broke down more quickly than average, while those dropped at the first two grazings at Great House broke down more slowly than average. It is difficult to suggest reasons for this difference other than that it may reflect differences in rainfall distribution, or rate of temperature build up in the spring, between the two centres. Alternatively, it is possible that the difference between the two centres was the result of the different classes of stock used. The beef cattle at Rosemaund grew considerably during the grazing season, and the muck pats dropped at the first two grazings would be much smaller than average. Muck pats dropped at Great House would be relatively constant in size since they were all produced by mature dairy cows, but would tend to be of thinner consistency at the start of the season.

Factors which were seen to affect the rate of muck breakdown were weather following deposition, (in that this determined whether or not the pat crusted) whether the pat was dropped on grazed or ungrazed herbage, and physical damage from birds, hooves or wheels.

It was noticeable at Great House that the sites on which muck pats had been deposited were frequently devoid of grass in the autumn.

At Rosemaund it was possible to study the rate at which contaminated areas were subsequently regrazed. These results are given in Table 6, and they refer only to areas which were contaminated at the first two grazings in 1969.

TABLE 6

Rate at which contaminated areas were regrazed

	Weeks after initial contamination					
	2	4	6	9	12	14
Per cent contaminated areas grazed	31	59	76	90	97	100

The rate at which these areas were regrazed reflects closely the rate of breakdown of the muck pats as shown in Table 5.

METHODS OF REDUCING REJECTION

When the level of rejection rose to the third or fourth grazing the practice at all three centres was to top paddocks, in order to reduce rejection at subsequent grazings. An assessment of the effect of topping was made at

Great House in 1969, in which one paddock was left untopped throughout the season and an adjacent one was topped after every grazing except the first. The results are given in Table 7.

TABLE 7

Effect of topping on per cent herbage rejection

Grazing number	Not topped	Topped
1	Nil	Nil
2	29	30
3	36	30
4	—	—
5	63	46
6	21	19

Unfortunately data for the fourth grazing was not obtained and this would probably have been the most interesting. There was a slight advantage to topping at the third grazing which increased markedly at the fifth grazing. On both treatments the high levels of rejection at the fifth grazing fell to acceptable levels at the sixth grazing. The implications of these results were that topping at every grazing was not necessary but that to top at the third or fourth grazing gave some advantage in mid-season. The fall in rejection on the untopped treatment between the fifth and sixth grazings may indicate that herbage rejected at early grazings became acceptable later in the season despite its lower digestibility.

At Rosemaund a trial was carried out in 1969 to compare normal management for cattle, including topping when necessary, with a system of grazing off rejected herbage with sheep. The results are shown in Table 8. The assessments of rejection were made after every cattle grazing, and before the sheep grazed the paddocks.

TABLE 8

Effect of sheep grazing on per cent herbage rejection by cattle

	Weeks of grazing season						
	2	4	7	9	11	16	21
Cattle only	9.5	17.4	27.4	13.8	18.2	30.0	40.3
Cattle followed by sheep	21.2	27.5	18.8	—	12.3	18.2	20.4

Grazing with sheep effectively substituted for mechanical topping, and the level of rejection from the treatment which involved sheep was much more even throughout the season. Muck pats on paddocks grazed by sheep broke down slightly more rapidly than those on paddocks grazed by cattle alone.

The effect of the sheep was not simply one of an increased stocking rate,

since there were no differences in performance of the cattle on the two treatments, and the amount of herbage conserved was only slightly depressed on the treatment involving sheep.

The problem of rejection can be overcome, on a proportion of the paddocks within a system, by alternating grazing and conservation. The longer the period over which these paddocks are out of the grazing sequence the more effective the reduction in rejection. Thus, as shown in Table 9, taking hay cuts at Great House was more effective than the silage cuts taken at Rosemaund.

TABLE 9
Effect of conservation on per cent herbage rejection

Grazing number	Great House	Rosemaund
1	Nil	57
2	25	58
3	52	52
4	} hay cut	silage cut
5		22
6	Nil	24

Since rejection depended on level of contamination, and this in turn was related to the rate of breakdown of muck, an assessment of the effect of harrowing on muck breakdown and rejection was made at Great House. Harrowing did not appear to accelerate breakdown but it did reduce the peak of rejection at the fourth grazing, as shown in Table 10.

TABLE 10
Effect of harrowing on per cent herbage rejection

Grazing number	Not harrowed	Harrowed
1	Nil	Nil
2	17	17
3	12	17
4	40	27
5	14	25
6	18	16

Finally, work at Great House has indicated that cows can be conditioned to eat contaminated herbage. Cows inside in winter were fed hay deliberately contaminated with cow muck, and bags of muck were hung in front of them. After about six weeks these cows were offered contaminated herbage and ate significantly more (81 per cent) than cows which had not been conditioned (33 per cent). At grass the conditioned cows spent slightly more time grazing contaminated herbage than those which had not been conditioned.

Attempts were made to encourage cows to eat contaminated herbage by spraying it with molasses, salt, aniseed and with commercially available odour masking compounds. None of these had any effect.

GENERAL CONCLUSIONS

The work at Rosemaund and Great House showed that contamination increased to about the third or fourth grazing, and that rejection built-up in a similar fashion. It was impossible to determine how much of the rejection at later grazings was due to actual contamination or to fall in digestibility, but there was no doubt that the initial rejection was due to the presence of muck.

No estimates were made of the effect that rejection had on animal production, but levels of rejection at Great House and Rosemaund rose to sufficiently high levels to indicate that animal performance may have been depressed. Estimates of rejection by dairy cows were much lower at Trawscoed. This may have been due to the technique employed there, but the workers at Trawscoed regarded rejection as much less of a problem except when cows were receiving supplementary concentrates.

In general rejection reached its highest levels when stocking rates did not fit herbage availability, and when rigid grazing systems were imposed. The problem of rejection was thus controlled by good grassland management, but if certain paddocks did reach very high levels of rejection the best control was topping either mechanically or grazing off with sheep, or, where possible, alternating grazing and mowing.

Appetizers and deodorants appeared to have little effect in reducing rejection, but animals could apparently be conditioned to eating contaminated herbage. It is possible that this process occurs naturally under well managed grazing systems and that it is not necessary to attempt deliberately to condition animals.

MAIZE FOR SILAGE

P. B. Harris, *Bridget's Experimental Husbandry Farm*

Attempts to grow maize for silage in this country have met with little success in the past. But with the development of new, earlier maturing varieties here and the introduction of others from abroad, the possibilities of the crop have again come under active consideration. To see whether the high yields of very digestible material reported from North America and Europe can be obtained in this country some investigations have been started in the past two years at three Experimental Husbandry Farms: High Mowthorpe in Yorkshire and Bridget's in Hampshire, both of which are on chalk soils, and Boxworth in Cambridgeshire on a calcareous clay soil.

Experimental work on the crop has been limited at High Mowthorpe. In 1968 three varieties, Kelvedon 59A, Pride 109 and Pride 116, were grown with 120 and 180 units of nitrogen per acre. Drilling was difficult in hard ground and subsequent bird damage led to poor establishment. The plant populations at the higher level of nitrogen used ranged from 28.5 thousand per acre for Pride 116 to 38.0 thousand for Kelvedon 59A, and the yields were 1.5 tons of dry matter per acre for Pride 116, 2.8 tons for Pride 109 and 3.8 tons for Kelvedon 59A. The yield of these two latter varieties was increased by 1 ton of dry matter per acre for the extra 60 units of nitrogen

applied. Dry matter percentages at harvest on 3 October ranged from 13 to 15 per cent. In 1969 a trial with Kelvedon 59A compared two seed rates of 41 lb and 53 lb per acre, at both 150 and 200 units of nitrogen per acre. Samples taken on 10 October and 23 October indicated dry matter percentages of 17.7 per cent and 18.2 per cent, and dry matter yields of 2.8 and 2.9 tons per acre respectively. At the first harvest there were increases in yield and dry matter percentage with the higher seed rate and nitrogen level but, these were not apparent at the second harvest. The differences in plant population which were apparent initially had disappeared by harvest when the mean population was 40,000 plants per acre.

At Boxworth in 1969 the varieties Kelvedon 75E, Inra 200 and Anjou 210 were compared. No estimates of yield were made but maturity of these three varieties, as judged on the dry matter percentage which was between 24 and 26 per cent, appeared similar when they were harvested early in October.

Observations on field crops were carried out in 1968 at Bridget's, and again in 1969 at Bridget's, Boxworth and High Mowthorpe. At Bridget's 10 acres of Kelvedon 33 were sown in 1968 and 7 acres of Kelvedon 59A in 1969. The use of a precision seeder was not very satisfactory on the flinty soil and birds attacked the crop despite the use of balloons. Establishment was difficult in both years and low plant populations of only 35,000 and 24,000 plants per acre resulted. 1968 was a wet year and while this produced good vegetative growth it delayed maturity so that when the crop was cut early in October, with the grain at the milky stage, the dry matter was only 21 per cent. In 1969, a much drier year with more sunshine, the crop matured earlier, though some varietal effect was also present, and by harvest in mid-October it had a dry matter content of 40 per cent with the grain mealy and becoming flinty. A small area of Kelvedon 75E appeared to be about 10 days earlier still.

Harvesting was by full chop forage harvester with a single row maize attachment. This worked well in 1969, but there were difficulties in the wet conditions of autumn 1968. The yields were 3.4 tons of dry matter in 1968 and 3.1 tons per acre in 1969, and each ton of dry matter harvested and stored required on average 3.0 man hours and 3.4 tractor hours.

In both years the total crop was ensiled in a vitreous steel tower. In 1968 when the crop was very wet seepage from the tower began almost immediately and continued for about three months. There was a high in-silo loss of 18 per cent of the dry matter ensiled, and the mechanical unloading of such wet material was found to be impossible. In 1969 no seepage occurred but some moulding of the silage took place at the top of the tower, despite the use of a polythene sheet.

Assessments of the nutritive value of the silage showed that in 1968 the *in-vitro* digestibility of the ensiled crop was over 70, but because of high in-silo losses in the wet material this was reduced during storage to 65. Crude protein content was also low at 9.0 per cent. However calves, sheep and dry stock readily ate the material. The 1969 crop was harvested at a more mature stage and, with no seepage, in-silo losses are likely to be much lower.

At High Mowthorpe a 5 acre observation area of Kelvedon 59A was sown covering the sides and bottom of a small dale. On the deeper soil of the dale bottom the maize was established satisfactorily. Here the plant population

was estimated at 48,000 per acre and yields of over 4 tons of dry matter per acre were obtained at harvest on 30 October, when the dry matter percentage was 20. On the thin soils on the dale sides which dried out rapidly no crop was established at all.

Establishment of maize was also difficult on the heavy soil at Boxworth where maize was drilled into a damp seed bed which later dried out and cracked. Bird damage also occurred and only one-third of the 5 acres of Kelvedon 59A that was sown produced a crop, the overall yield being less than 1 ton of dry matter per acre. At harvest the crop contained 39 per cent dry matter, similar to that recorded at Bridget's.

The results of this work at the three farms show that yields of over 3 tons of dry matter per acre can be obtained from maize, but that it is not an easy crop to grow. While a highly digestible silage can be produced, the dry matter content and the level of protein are often low.

The use of atrazine at all three farms kept the crop free from most weeds except at Boxworth in 1969 when the dry conditions reduced the herbicide's effectiveness. The sowing date in May leaves time for early cultivations so that maize can be a valuable cleaning crop, although its late date of harvest does not allow much time for preparation if it is intended to follow it with winter wheat.

ADDING SUCCESSIVE SMALL CUTS TO A VACUUM SILO

S. F. Clench, *Liscombe Experimental Husbandry Farm*

The vacuum compression method of silage making was investigated at Liscombe from 1965 to 1968. It was found that there was only a slight reduction in fermentation loss, but a considerable reduction in the proportion of visible rotted silage was achieved compared with normal clamp silage.

These investigations also showed that the vacuum method might be suitable for conserving successive small cuts of silage during the season without layers of waste silage being produced down through the silo, thus storing maximum herbage with minimum waste.

At the same time a series of grass management investigations showed that total aftermath production was greater the earlier the first silage cut was taken, and that the majority of the aftermaths when cut at monthly intervals were above 68 per cent digestibility (per cent digestible organic matter in the dry matter) and few fell below 66.5 per cent.

Thus it seemed that by continuously cutting and conserving young grass of high digestibility it should be possible to consistently produce a high quality bulk food capable, for example, of winter fattening 6 cwt bullocks. Furthermore by repeated cutting, only a small initial acreage would be required. This could be beneficial to upland and hill farmers where level fields suitable for conservation are at a premium.

The technique has been under investigation over the last three years. During this time 84 tons of silage dry matter have been conserved from 30½ acres by repeated cutting and vacuum ensilage. The herbage had been cut from perennial ryegrass white clover leys, 5–8 years old.

TABLE I

Cutting dates and herbage yields

Year and acreage	Date of 1st cut	Number of subsequent cuts	Interval between cuts	Dry matter removed (tons)
1966				
11.5 acres	13 May	4	3/4 weeks	32.2
1967				
11.5 acres	5 June	2	5/6 weeks	30.9
1968				
7.5 acres	19 May	2	5/6 weeks	20.6

During the first year no wilting was attempted and molasses was added to all herbage ensiled at the rate of 2 gallon per ton of fresh material. The following two years slightly more mature herbages, wilted to give silages of high dry matter content (34 and 37 per cent) with digestibility values of 69 and 66 per cent, were used.

The conservation technique was that normally associated with vacuum silage, namely cutting by forage harvester, stacking the cut grass on a polythene sheet, and when the stack was completed covering and sealing it with a second polythene sheet. Finally all air was removed, by means of a vacuum pump, to 15 in. of mercury pressure. After each subsequent filling the silos were re-evacuated to 10–15 in. of mercury pressure. At the end of the season they were covered with old polythene sheets held firmly against the surface of the silage by plastic fertilizer bags, old molasses drums or railway sleepers.

In all three years the silos were opened in October and fed through the winter until April.

Visible wastes, apparent on opening the silos, or forming by secondary fermentation during the winter feeding period, varied in direct relationship to the dry matter of the resultant silage. Thus in the first year with a low dry matter silage of 17 per cent there was no visible waste in any part of the silo. However, in the subsequent years, when wilted silage was made and the dry matter of the silage was higher, the amount of visible wastage increased. This was due partly to mouldy patches in the freshly opened silage but was mainly because moulds developed during the period of winter feeding. Silages with a dry matter content above 35 per cent are not suitable for this conservation technique as the wastage due to moulds developing through a long winter feeding period can be in excess of 20 per cent of the dry matter conserved.

The silages were fed alone in the first two years' winter fattening trials, to groups of 14 month old Hereford x Friesian steers weighing 6½ cwt at yarding. Liveweight gains achieved were 1.2 and 1.5 lb per day, the latter rate of gain being sufficient to fatten the animals on a silage only diet. The third year's trial attempted to fatten older animals, namely 2½ year old, 8½ cwt bullocks. Although these gained weight for two-thirds of the winter fattening period at 1.4 lb per day they required a supplementary feed of 5½ lb of

rolled barley per head for the latter third of the winter to achieve the required 'degree of finish' at slaughter, Nevertheless these animals only consumed $3\frac{1}{2}$ cwt of barley per head during the overall fattening period.

SUMMARY AND CONCLUSIONS

From observations on this conservation technique it is apparent that by repeated cutting and conserving young grass of high digestibility a large tonnage per acre of a high quality bulk feed can be produced. The technique has the further advantage that only small acreages are required for each cut. These can be cut, wilted and conserved in a short space of time, taking maximum advantage of favourable weather conditions. The silo can also be sited at any required point on the farm without undue site preparation or expensive silo capital costs.

Over the three year period the method enabled 84 tons of dry matter to be conserved from $30\frac{1}{2}$ acres, with a digestibility value which varied from 66–70 per cent DOMD.

To ensure sufficient nutrient intake for fattening the silage must be of high dry matter (25–30 per cent) and high digestibility (68–70 per cent DOMD). To obtain this will mean a fair degree of 'wilting' must be achieved and that the aftermaths must be cut at 5 to 6 week intervals. Should wilting be excessive and a very high dry matter silage result (over 35 per cent DM) visible waste due to secondary fermentation will result in very high losses. Regardless of the type of silage that results, the extra physical work involved in stack building, repeated sealing and evacuation must be undertaken if this technique is employed, and there is also the difficulty of keeping the top vacuum sheet pressed firmly against the surface of the silage. These disadvantages must be weighed against the ability to conserve a sequence of high quality cuts from a limited acreage.

FORMIC ACID FOR SILAGE

D. O. Williams, *Great House Experimental Husbandry Farm*

Although hay represents more than 80 per cent of all fodder conservation, silage-making has consistently increased in importance year by year and is an integral part of many farming systems. The objective in silage-making is to provide a winter food for stock which is of high quality and from which the production of as much meat or milk as possible can be obtained. Improvements in the nutritive value and quality of silage should reduce requirements for expensive concentrates. The most important factor affecting the feeding value of silage is the stage of growth at which the herbage is cut, but since unsatisfactory fermentation reduces both feeding value and silage intake a potentially high feeding value can be lost unless the silage is well made.

PRE-TREATMENT AND ADDITIVES

The features of a good silage fermentation are as follows. Plant respiration, enzymic fermentation and aerobic microbial growth rapidly exhaust the limited amount of oxygen within the silage, and providing the oxygen supply is not replenished the aerobic organisms are suppressed and the anaerobic micro-organisms become dominant. Most significant at this stage are the lactic acid bacteria which ferment sugars to lactic acid. Copious production of acid ensures that the pH falls rapidly in unwilted material to around 4.2, at which point silage will remain stable because deleterious bacteria are inhibited. Most significant of the harmful bacteria are the clostridia, whose development is favoured by high moisture content in the silage, combined with a relatively high pH. Clostridial activity is indicated by the production of butyric acid and destruction of protein and amino-acids.

The ways in which pre-treatments and additives affect the fermentation process must be examined if their usefulness is to be assessed. They can be used to remedy adverse silage-making situations either by encouraging the development of beneficial bacteria or by suppressing deleterious bacteria. For example, pre-wilting reduces moisture content and increases the concentration of sugars. There is a two-fold benefit from this as clostridia are suppressed by the rise in osmotic pressure and low moisture content of the silage, and the lactic acid bacteria are stimulated by the increased concentration of sugars. Laceration, chopping and crushing which expose a plentiful supply of cell contents encourage rapid bacterial growth and improve the fermentation.

Effective additives do a similar job. Molasses, the cheapest additive, is a source of sugars and provides a fermentable substrate for lactic acid bacteria. The sugars are converted to lactic acid, pH falls rapidly and good preservation is initiated.

In many experiments direct acidification, generally referred to as the A.I.V. process, has proved to be a most effective method of ensuring good preservation of silage. The acid acts by reducing the pH value straight away to a level at which clostridia are inhibited. Various organic and mineral acids have been used for many years but they have remained unpopular because they are dangerous and difficult to mix with the silage. A further disadvantage is that surplus acid which may persist in the silage can cause scouring when fed to stock. For this reason the acid required must be calculated precisely or a neutralising agent fed.

About 25 years ago workers in Norway found that dilute formic acid when compared with the A.I.V. process produced a silage with a better feeding value which was relished by stock and had no drawbacks due to the acid in the diet. Formic acid can be metabolised by the ruminant and was not harmful at the levels found in treated silage. A major disadvantage however was that the formic acid was diluted in water and this increased the volume of effluent from the silage.

Five years ago the Norwegian workers developed equipment to spray concentrated formic acid onto herbage as it passed through the flail chamber of a forage harvester. This method has two advantages; a low volume of liquid is applied, and grass and acid are thoroughly mixed. The acid flows by gravity from a five-gallon polythene container mounted in a holder on

the chute of the forage harvester. The rate of flow is adjusted by changing the size of spray nozzle.

E.H.F. TRIALS WITH FORMIC ACID

Method

The equipment described, which provides a simple and safe way of dispensing small volumes of formic acid onto herbage, was made available to British silage-makers in 1967. Experiments commenced that year on Experimental Husbandry Farms to test formic acid in British conditions. In Table 1 it can be seen that the first experiments compared wilted herbage treated or not treated with formic acid. Wilted herbage was used as the control treatment because wilting has consistently given excellent silage in extensive trials. It was therefore decided that the effect of formic acid should be assessed against wilted herbage. In addition, during 1968 at Great House formic acid was used on fresh herbage, and in 1969 at Drayton formic acid was used on fresh herbage, and a fresh untreated herbage control was also included in this trial. At Liscombe formic acid was compared with molasses on fresh grass. The results of these trials will therefore provide a comprehensive assessment of the value of formic acid on both wilted and fresh herbage. Formic acid was applied at $\frac{1}{2}$ gallon per ton of herbage in 1967 and 1968 and at $\frac{3}{4}$ gallon per ton in 1969.

TABLE 1
Silage additive experiments

Year	E.H.F.	Herbage treatments	Herbage per treatment (tons)
1967	Great House	Wilted v wilted + F.A.	16
	Drayton	Wilted + F.A. (no control)	24
1968	Great House	Wilted v fresh + F.A.	22
	Drayton	Wilted v wilted + F.A.	25
	Liscombe	Wilted v wilted + F.A.	72
1969	Great House (a)	Wilted v fresh + F.A.	14
	Drayton	Wilted v fresh v fresh + F.A.	20
	Liscombe	Fresh v fresh + molasses v fresh + F.A.	140
	Great House (b) (in plastolene bags)	Wilted v wilted + F.A. v fresh v fresh + F.A.	2

Herbage was cut with a knife mower on all treatments to give a uniform level of cut. A double-chop harvester was used at Drayton to pick up the herbage and flail harvesters at the other centres. The period of wilting was 24 hours.

Silages were made in roofed bunker silos with concrete or wooden walls. Herbage was weighed into each silo, dry matter ensiled assessed and chemical constituents analysed. Care was taken in all cases to seal the silos as efficiently as possible after consolidation, by use of plastic sheets weighted down with straw bales.

Progress of fermentation was monitored in some of the trials by chemical and bacteriological analysis of cored samples. Temperatures in the silos were recorded and volume of seepage measured automatically. The silage ensiled at Great House in 1967 was opened for feeding on 6 March 1968, and the 1968 silage was opened on 1 February 1969. At Drayton the silages were opened in November and at Liscombe, where feeding continued for nearly five months, on 31 October. All silages were weighed out during the feeding period and the quantity of dry matter fed determined. Loss of dry matter during storage was calculated and surface spoilage weighed. Silages were chemically analysed to indicate their quality and the type of fermentation which had occurred, and finally they were fed to stock to compare feeding values.

Silage quality

The chemical analyses of herbage ensiled and of the silages fed are given in Table 2 together with other characteristics which help to define these materials.

TABLE 2

Herbage and silage quality

	Great House, 1967		Great House, 1968		Drayton, 1968		Liscombe, 1968	
	Wilted	Wilted +F.A.	Wilted	Fresh +F.A.	Wilted	Wilted +F.A.	Wilted	Wilted +F.A.
<i>Herbage data</i>								
Grass varieties	Timothy, meadow fescue, <i>Poa spp.</i>		Timothy, meadow fescue, <i>Poa spp.</i>		S.24 perennial ryegrass		Perennial ryegrass, white clover	
Date harvested	28 June		4 July		22 May		10-17 June	
Nitrogen units/acre	60		60		100		60	
Dry matter per cent	23.6	24.1	30.7	21.4	25.4	26.3	32.2	32.8
Sugars per cent	6.8	7.1	5.5	5.1	17.2	12.2	n.a.	n.a.
Crude protein per cent	14.5	13.9	13.2	13.5	14.5	14.8	15.4	16.1
<i>Silage data</i>								
Dry matter (toluene) per cent	22.6	24.2	27.5	20.1	24.3	23.9	33.9	32.2
Crude protein per cent	16.0	14.0	14.7	14.4	15.3	15.2	15.2	15.9
pH	5.0	4.2	5.0	4.7	4.6	4.3	4.7	4.5
Maximum temp. °F	89	79	110	84	83	74	n.a.	n.a.
Lactic acid mg/ml	8.5	22.4	8.1	6.8	14.0	22.9	22.8	28.7
Butyric acid mg/ml	11.4	2.9	10.0	6.9	n.a.	n.a.	n.a.	n.a.

The principal features which may be noted are that formic acid treated silages had cooler fermentations and lower pH values than control silages. Lactic acid concentration was increased in all treated silages except in the fresh herbage silage at Great House.

The sugar levels in the herbage are of great interest. At Drayton the perennial ryegrass was rich in sugars even though early cut and heavily

manured. The lactic acid level was higher in the treated silage, which also had a lower pH, although both treated and control silages had excellent fermentations. The wilted silages made at Liscombe were excellent as would be expected for sugar-rich perennial ryegrass herbage ensiled at optimum dry matter content. However the acidity of the treated silage was greater. In contrast, at Great House the low sugar content of the timothy/meadow fescue/*Poa* herbage even when relatively mature is notable. When wilted and treated with formic acid this material developed an excellent fermentation with low pH and high level of lactic acid in the silage. The wilted control was slightly butyric.

Formic acid treated fresh herbage had a cooler fermentation than the wilted control in 1968 and although low in lactic acid it was less butyric than the control silage.

The precise effect of pre-wilting and additives on the silage-making process cannot be fully assessed from the herbage and silage analyses given in Table 2: for a complete evaluation the whole sequence of changes occurring between ensiling the herbage and feeding the silage more than six months later must be followed.

Effect of formic acid on silage fermentation

Cores of silage were extracted periodically from silos at Drayton in 1968 and at Great House, Liscombe and Drayton in 1969 to provide details of pH, sugar and lactic acid changes. Analyses have not been completed for silages ensiled in 1969 but data from Drayton and Great House for the period from one day to 10 days after ensiling is included because of its importance.

TABLE 3
Chemical changes after ensilage

	Days after ensilage	pH	Sugars in D.M. per cent	Lactic acid mg/ml	pH	Sugars in D.M. per cent	Lactic acid mg/ml
Drayton 1968		Wilted			Wilted + F.A.		
	1	6.4	17.2	n.a.	5.1	12.2	n.a.
	5	4.4	8.9	n.a.	4.8	13.9	n.a.
	10	4.2	n.a.	n.a.	4.6	n.a.	n.a.
	51	4.4	3.3	22.8	4.3	8.7	24.4
	180	4.6	2.2	14.0	4.3	3.4	22.9
Drayton 1969		Wilted			Fresh + F.A.		
	1	5.9	13.7	3.2	4.4	20.6	1.3
	3	5.2	4.8	21.9	4.4	20.6	1.1
	10	4.8	4.8	29.5	4.4	18.8	2.3
		Fresh					
	1	n.a.	19.4	1.4			
	3	5.2	14.4	6.7			
	10	4.2	6.4	18.6			
Great House 1969		Wilted			Fresh + F.A.		
	1	5.9	12.1	0.7	4.6	11.6	0.6
	3	5.5	4.9	7.6	4.7	9.6	2.6
	10	5.0	4.9	13.6	4.4	7.7	8.2

n.a. = not available

The application of formic acid at once reduced the pH value of the herbage. The sugars were not fermented rapidly and there was a gradual build up of lactic acid with a further fall in pH. In the wilted control silages the changes were quite different. The pH value fell as the lactic acid level increased and at the same time the sugars disappeared. At Drayton in 1969, the wilted silage at day 3 contained 22 mg/ml lactic acid and only 4.8 per cent sugars remained. The fresh silage had only 6.7 mg/ml lactic acid at this stage but 14.4 per cent sugars remained. In the fresh silage treated with formic acid the sugars were virtually unaffected although a little lactic acid had developed. Changes in the Great House silage were similar, although in the formic acid treated silage the pH was reduced from 4.6 to 4.4 by day 10 due to a considerable production of lactic acid. In the wilted control the pH had not fallen below 5.0 at day 10, but in this silage deleterious bacteria were probably suppressed by the low moisture content.

Bacteriological examination of the Drayton silages showed that formic acid treated silages contained reduced numbers of bacteria, in particular very few *Lactobacilli*, which explains the conservation of sugars. Further study of changes in chemical constituents and in types and numbers of bacteria will, it is hoped, reveal the later patterns of development in the silages. Formic acid treated silages at Great House contained very large numbers of lactic acid bacteria when the silages were being fed, and it appears likely that they developed at a later stage than in the control silages which contained more harmful bacteria.

Loss of dry matter in the silo

Losses of silage dry matter were slightly greater in untreated wilted silage at Great House and Drayton but at Liscombe treated wilted silage had higher losses of dry matter as shown in Table 4. The use of formic acid appears to have had little effect in reducing fermentation losses, although the analyses show that it maintained low pH and high lactic acid levels and at Great House reduced the formation of butyric acid.

TABLE 4

Partition of dry matter as per cent herbage ensiled

	Great House, 1967		Great House, 1968		Drayton, 1968		Liscombe, 1968	
	Wilted	Wilted +F.A.	Wilted	Fresh +F.A.	Wilted	Wilted +F.A.	Wilted	Wilted +F.A.
Edible silage	74.3	75.7	78.1	78.6	75.1	77.6	77.8	72.7
Fermentation losses	25.7	24.3	21.9	19.4	20.3	17.4	13.3	17.8
Surface spoilage	—	—	—	—	4.6	4.8	8.9	9.5
Loss of effluent	nil	nil	nil	2.0	nil	0.2	n.a.	n.a.

The 1969 trials included fresh herbage which is less likely to produce a good fermentation than wilted silage. Formic acid was used on fresh herbage and the results may demonstrate that by preventing decomposition in low dry matter silage it has an economic role to perform. At the time of writing the silages are still being fed to stock.

Secondary aerobic surface spoilage was not reduced at Drayton and Liscombe, and no fungicidal effect of formic acid on degree of moulding was observed. At Great House in 1967, spoilage was similar in both silages, but in 1968 the wilted silage deteriorated more quickly than direct cut treated silage, after the silos were opened.

Two per cent of the dry matter loss of the direct cut silage at Great House ran off in the effluent, 455 gallons of seepage being recorded or two tons of liquid from 22 tons of herbage. The pollution problem from effluent seeping from unwilted silage and reaching water-courses is another incentive for wilting, despite the possibility of some dry matter loss during wilting in the field.

Feeding value of formic acid silage

The nutritive values of the experimental silages were assessed when fed to wether sheep in digestibility crates. The silages were also fed to farm stock to compare acceptability, dry matter intake and daily liveweight gain or milk yield. No harmful effects from feeding treated silage were observed. Results of the completed trials are given in Table 5.

TABLE 5

Formic acid silage feeding trials 1967-68

Centre	Stock fed each silage	Silage	Digest- ibility D.O.M.D. per cent	Dry matter intake (lb)		Daily liveweight gain (lb)
				Silage	Concen- trates	
Great House 1967	Six, 5 cwt. Friesian heifers	Wilted	54.8	13.6	nil	0.8
		Wilted + F.A.	59.0	14.4	nil	1.2
Great House 1968	Six Friesian dairy cows	Wilted	57.2	17.0	9.5	37 lb milk/day
		Fresh + F.A.	62.9	17.0	9.5	39 lb milk/day
Drayton 1968	Twenty-one, Hereford x Frie- sian steers, 4cwt	Wilted	66.8	8.8	3.4	2.08
		Wilted + F.A.	69.2	8.6	3.4	2.01
Liscombe 1968	(a) Five, nine month old Here- ford x Friesian steers	Wilted	64.4	10.9	nil	0.88
		Wilted + F.A.	66.9	10.1	nil	0.90
	(b) Seven, 15 month old Devon x Friesian heifers	Wilted	64.4	14.4	3.2	1.62
		Wilted + F.A.	66.9	13.7	3.2	1.60

The outstanding feature was the consistently higher digestibility of silages treated with formic acid. The improvement was most marked at Great House. Treated wilted silage in 1967 contained about 9 per cent more digestible nutrients in the dry matter than the control. Direct cut treated

silage in 1968 showed a similar improved preservation of digestible nutrients compared to the wilted control silage.

Friesian heifers at Great House ate more treated silage, fed without supplementation, and made greater liveweight gains. The control silage was slightly butyric (Table 2) and was accepted less readily. Dairy cows fed direct cut treated silage to provide maintenance and one gallon, with concentrates declining at $2\frac{1}{2}$ per cent per week, gave slightly more milk than those fed wilted silage. They maintained body weight on treated silage but lost a little when fed the wilted silage ration.

Wilted silages fed at Drayton to yearling steers indicated little difference in feeding value. At Liscombe beef cattle in both trials tended to eat more of the less digestible untreated silage to produce liveweight gains similar to the cattle fed treated silage.

CONCLUSIONS

Wilted silage

Trials with crops made into wilted silages at Great House, Liscombe and Drayton in 1967 and 1968 showed that preservation of dry matter was only slightly affected by the use of additives. Invisible losses, resulting from plant respiration and the activity of microorganisms, were not reduced in all trials nor was a consistent reduction in surface spoilage measured. The reason for this result may lie in the good silage-making techniques used for the control treatments against which the additives were compared; lacerated or chopped wilted grass was well consolidated in the silos. The silages were sealed by covering the surface of the silage with plastic sheet; this was probably the dominant factor which led to the result that losses of dry matter from both trial silages were similar. It is probable that losses were nearly minimal for this type of silo and the addition of formic acid to wilted herbage was therefore ineffective.

Nevertheless, the preservation of digestible nutrients was increased in wilted silages by formic acid. The fermentations were cooler and the treated silages were rich in lactic acid. The extra content of digestible organic matter (D.O.M.) was confirmed in feeding trials.

Wilted silages made with formic acid at Great House and Drayton contained around 20 lb D.O.M. more per ton of herbage conserved than untreated silage. The energy value of this improvement could have been supplied by less than 25 lb of barley, whereas the cost of applying $\frac{1}{2}$ to $\frac{3}{4}$ gallon formic acid per ton of herbage was between six and nine shillings. The direct financial benefit of the additive in these trials therefore appears to be nil.

Fresh silage

Silage made from low dry matter direct cut herbage is frequently butyric, because in this type of silage insufficient lactic acid is produced to prevent clostridial wastage. In this situation the use of formic acid might reduce dry matter losses, prevent deterioration of digestible nutrients and be well worthwhile in cash terms. This probability is indicated by the good preservation of direct cut herbage at Great House in 1968 when the use of formic acid gave results equivalent to wilting.

The trials still in progress will enable the benefit of formic acid as an additive for unwilted herbage to be costed. Some farmers like to proceed with silage-making whatever the weather, particularly in the western and wetter areas where wilting is not always possible, and for them additives may have a considerable value if the cost is reasonable.

HAY ADDITIVES

G. D. Badger, *Drayton Experimental Husbandry Farm*

Trials on selected additives have been carried out at Trawscoed, Boxworth Great House, Liscombe and Drayton Experimental Husbandry Farms in the last three seasons, and the trials on hay cut in 1969 are still in progress at the last three farms. The following commercial products and organic acids have been tested during the last three years.

Hayguard
Hay Savor
Propionic acid
Formic acid
Acetic/formic and mixtures
Formic/propionic and mixtures

The trials were carried out on relatively small quantities of up to 50 bales with moisture contents in the 25–40 per cent range. The proprietary compounds were applied by specially designed applicators while the organic acids were dispersed on the hay by means of jets discharging into the mouth of the baler. Of the commercial applicators, one discharged into the mouth of the baler and the other into the baling chamber.

So far experience with additives has been most disappointing, propionic acid being the only one to show any real promise; even with this acid its range of use, employing current application techniques, would appear to be limited by both moisture content and cost. Experience suggests that 30 per cent moisture is near the upper limit at which treated hay may be baled, and to achieve satisfactory preservation an application rate of 2–3 per cent by weight of acid is required. At current prices for propionic acid this represents a charge for materials only of around £3 per ton; by this expenditure one would be enabled to bale hay 10 per cent wetter than usual which might represent a shortening in the curing period of possibly a day.

The major problem at present appears to be to improve the efficiency of application, for laboratory experiments suggest that it may be possible greatly to reduce the rate of application provided a thorough distribution of acid is achieved. At present, the future of the additives so far tested is not encouraging, but the fact remains that haymaking is still by far the most important method of conserving grass in this country, and a cheap method of shortening the curing period by 1 or 2 days could greatly increase the prospects of completing haymaking during a dry spell. Also, efficient preservation of earlier cut hay would enhance the quality of the fodder compared with traditionally made hay normally cut at a fairly mature stage. The hope is that improved application techniques for propionic acid will be developed, otherwise the prospects are not bright.

Livestock

DRIED GRASS FOR DAIRY COWS

A. L. Francis, *Bridget's Experimental Husbandry Farm* and

G. Alderman, *Regional Nutrition Chemist, N.A.A.S. South East Region*

A renewal of interest in feeding dried grass to dairy cows was first shown at Great House E.H.F. in 1966. A high quality (18 per cent protein, 64 per cent digestibility) dried grass in the conventional pellet of hammer milled material was used as a dairy concentrate at 4 lb per gallon of milk. It was compared with normal dairy concentrate fed in addition to a maintenance ration of average quality seeds hay.

During the experimental period of eight weeks, milk yields of the dried grass fed cows declined to a greater degree than the control fed cows, but there were no significant effects on milk quality. These results suggested that the rate of feeding of the dried grass pellets should be increased to 5 lb per gallon if equality with normal concentrates was to be achieved.

Accordingly the experiment was repeated in a similar form in 1967 using dried grass pellets of 15 per cent protein and 62 per cent digestibility at 5 lb per gallon of milk in addition to a maintenance ration of hay. The dried grass fed cows again declined in milk yield rather more than the control group, but they did not lose weight significantly whereas the control group did. Milk quality was slightly lower on the dried grass treatment.

A possible weakness of these preliminary experiments was that no mineral supplementation of the hay and dried grass treatment was included. Subsequent analysis of the feeds revealed deficiencies of major and trace elements. It was also noted that cows giving 5 gallons had difficulty in eating all their rations, i.e. 15 lb hay and 25 lb dried grass.

In 1968 experiments on feeding dried grass to dairy cows were extended to include all four dairy E.H.Fs.—Boxworth, Bridget's, Great House and Trawscoed. It was also decided to compare conventional pellets of hammer milled dried grass with cobs produced by direct pressing of chopped dried grass through a $\frac{1}{2}$ inch rotary die press. This technique was reported to give a longer staple length in the cobs thus reducing the need to feed long fibre to the cow to maintain satisfactory butterfat levels.

The production of adequate tonnages of high quality dried grass in both cob and pellet form from the same crop presented difficulties, particularly as the decision to undertake these trials was only made in mid-summer. A first cut of maiden Italian ryegrass was harvested under difficult wet conditions in the autumn of 1968 by a large grass drying plant. The grass averaged 18 per cent protein and 68 per cent digestibility, but had a high silica content due to soil contamination.

A particle size analysis was carried out on a representative sample of both pellets and cobs by the Dairy Husbandry Department of the National Institute for Research in Dairying, and the results were as follows:

	Pellets	Cobs
Per cent passing No. 7 sieve	99.2	98.5
14 "	92.4	90.8
25 "	75.5	63.7
52 "	49.7	34.5
100 "	19.3	14.3
Modulus of fineness	1.64	1.98
Modulus of uniformity	0.2:8	0.4:6

The particle size in the cobs was small and did not differ appreciably from hammer milled material except in the very small fraction of less than 1 mm long. It would appear that a substantial amount of grinding takes place in a rotary die press when fed with chopped dried grass.

Great House and Trawscoed used Friesian heifers to compare 5 lb per gallon of cobs or pellets fed in addition to a maintenance ration of hay or silage.

Minerals were fed in a daily supplement of 1 lb per head of rolled barley. Only a limited number of animals could be put on trial so that significant differences were not obtained. However, both centres obtained indications that cobs were less satisfactory in sustaining milk production than either pellets or normal concentrates. Heifers took some time to get used to eating cobs and consistently rejected small quantities. No rejections of dried grass pellets were noted. Butterfat levels showed wide variations, with lower levels recorded for dried grass pellets, and lower solids-not-fat levels were obtained from the cob fed animals at Great House.

Boxworth and Bridget's studied a rather different situation, using a combination of dried grass and rolled barley for both maintenance and production, together with minimum amounts of barley straw. Cobs and pellets were compared against a control ration which was a conventional straw plus balancer diet. The treatment rations fed are shown below.

	Control	Dried grass cobs	Dried grass pellets
Maintenance	12 lb straw + 6 lb concentrates	5 lb straw + 5 lb cobs + 5 lb barley	10 lb straw + 4 lb pellets + 3 lb barley
Production per gallon	4 lb concentrates	3 lb cobs + 2 lb barley	3 lb pellets + 2 lb barley

Since more individual feeding facilities are available at these centres, eight cows (mainly Friesian) were fed on each treatment at each farm. The full results adjusted by covariance analysis are given in the following tables.

Boxworth

	Daily milk yield (gal)	Butterfat per cent	Solids- not-fat per cent	Total solids per cent	Daily live weight gain (lb)
Control	3.17	3.84	8.67	12.51	+0.37
Cobs	3.40	3.65	8.52	12.17	+0.40
Pellets	3.54	3.66	8.64	12.30	+0.14

Cows fed on dried grass pellets and barley gave more milk than those fed the straw plus balancer diet, but milk quality differences were small, although pellets showed the lowest total solids. All animals increased in weight slightly during the 12 week experimental period.

Actual concentrate consumption (dried grass and barley) averaged 5.6 lb per gallon for cobs and 5.2 lb per gallon for pellets compared to 5.3 lb for the control. All the straw offered was consumed, but cobs were occasionally refused and cows took longer to eat them.

Bridget's

	Daily milk yield (gal)	Butterfat per cent	Solids- not-fat per cent	Total solids per cent	Daily live weight gain (lb)
Control	2.95	3.85	8.63	12.48	+0.19
Cobs	2.99	3.48	8.07	11.55	+0.25
Pellets	3.45	3.54	8.29	11.83	-0.04

At Bridget's also the dried grass pellets plus barley treatment gave the highest milk yield, nearly 5 lb per day better than the control or the cobs plus barley treatment. The performance of the control cows was poor compared to previous years' experience, suggesting that the feeding value of the barley straw was appreciably lower. An '*in vitro*' digestibility test recorded a value of only 30 per cent for the straw fed in this trial.

This may also explain the marked changes in milk quality recorded at Bridget's in contrast to those at Boxworth. Marked declines in both solids-not-fat and butterfat levels occurred, with total solids of 11.8 per cent for pellets and 11.6 per cent for cobs. Milk of this quality would not be acceptable by the Milk Marketing Board. Normal levels of total solids were obtained on the control treatment.

In order to obtain further information about the feeding value of dried grass for dairy cows and because there is some evidence that autumn crops of grass of high digestibility may have a low net energy value or Starch Equivalent, these trials are being repeated in 1969/70 using mainly second cut ryegrass of over 70 per cent digestibility. Either 2 lb or 3 lb of dried grass, each combined with 2 lb barley, per gallon of milk are being compared at Boxworth and Bridget's, as well as continuing the comparison of cobs and pellets. Four different maintenance rations are being used.

Boxworth:	barley straw, concentrates, dried lucerne and barley.
Bridget's:	cereal silage, dried grass and barley.
Great House:	seeds hay, dried grass and barley.
Trawscoed:	grass silage, dried grass and barley

Only tentative conclusions can be drawn at this stage in the experimental programme on dried grass. The true feeding value of dried grass for dairy cows cannot yet be clearly stated since it appears to be able to affect the partition of energy between milk and body gain.

Certain physical disadvantages of cobs as produced at present have been noted, in particular their hardness, slow rate of eating and occasional rejection by cows. The rotary die presses used to produce the cobs tested in

1968 did not preserve the long fibre characteristics of the dried grass and long roughage was still required in the ration at about 8 lb per head daily. The effects on milk quality noted during these trials require further study so that firm recommendations on suitable specifications for dried grass for feeding to dairy cows can be made. Dried grass fed as a concentrate ration for dairy cows requires careful mineral supplementation and feeding in equal parts with rolled barley obviously facilitates this.

The feeding value of different samples of dried grass varies considerably, and from the economic point of view its price should be related to its quality and the rate at which it can be substituted for other feeds. At £27 per ton, dried grass compares unfavourably with balanced concentrates at £30 per ton if 5 lb dried grass rather than 4 lb balanced concentrates are required per gallon of milk. In this situation a price of about £24 per ton for dried grass would be equivalent to £30 per ton for normal concentrates. However, if a high protein sample of dried grass is available, it can be mixed in equal parts with rolled barley, and on the evidence of the trials reported here, 5 lb per gallon of this mixture should give satisfactory results, providing a small quantity of barley straw is also fed. Costing rolled barley at £22 per ton and dried grass at £27 per ton the mixture will cost £24 10s. per ton. The higher protein dried grasses used in the trials so far are well suited to this method of feeding.

FEEDING CONCENTRATES TO SPRING CALVING COWS AT GRASS

M. L. Yeo and L. R. Gurnett, *Trawscoed Experimental Husbandry Farm*

From 1956 to 1962 it was demonstrated at Bridget's Experimental Husbandry Farm that feeding supplementary concentrates to spring calving cows receiving unrestricted quantities of grass was not profitable. However, the stocking rate was under 1 cow per acre. In 1965 it was decided to run a pilot trial to see if worthwhile milk increases could be obtained by feeding concentrates to cows at higher stocking rates. When spring calving cows were stocked at 2 cows per acre and fed 11 lb of concentrates per day, 1,200 gallons of milk were produced per acre; further intensification was considered to be justified. The nitrogen application was increased to 400 units per acre and the level of concentrate feeding reduced.

The following results were obtained:

Milk yields at Bridget's, 1966

	Low	Stocking rate High	
Cows grazed/acre	1.5	2.27	2.27
Concentrates lb/cow/day	2	2	6
Milk yield gal/acre	843	1,309	1,442

No economic response was obtained by feeding extra concentrates at the high level of stocking and even further intensification was investigated.

At Trawscoed in 1967 three small herds of spring calving cows were allocated to grass paddocks at the rate of 2 cows per acre. After the initial feeding period following turnout to spring grass had ended, one herd was not given any more concentrates. The second herd, however, continued to receive 4 lb of ground barley per head per day throughout the grazing season. The third herd which did not receive any barley was changed to aftermath grazing mid-way through the season, as it was considered that fresh pasture offered at this time might give a boost to milk yield. However by mid-season the lactation is well advanced and any improvement in milk yield is likely to be only small. In fact with 2 cows per acre it was found that the feeding of barley had little effect on milk yield and was thus uneconomic, but the vast amount of grass uneaten suggested that a higher stocking rate would be possible.

Milk yields at Trawscoed, 1967

	No barley	4 lb ground barley/cow/ day	Aftermath grazing, no barley
Cows grazed/acre	2.0	2.0	2.0
Milk yield gal/acre	1,112	1,056	1,169

In 1967 at Bridget's the stocking rates were further increased and the highest stocking rate was 3 cows per acre.

Milk yields at Bridget's, 1967

	Stocking rate		
	Low		High
Cows grazed/acre	1.75	3.0	3.0
Concentrates lb/cow/day	2	10	14
Milk yield gal/acre	1,109	1,575	1,713

Milk yield was higher than in the previous years, but again, even at this very high stocking rate, feeding of extra concentrates did not produce extra profits.

In 1968 the same stocking rate was maintained at Bridget's but the concentrate feeding was decreased, while at Trawscoed the stocking rate was increased to 2½ cows per acre, all other aspects remaining the same. The following results were obtained.

Milk yields at Trawscoed, 1968

	No barley	4 lb ground barley/cow/ day	Aftermath grazing, no barley
Cows grazed/acre	2.5	2.5	2.5
Milk yield gal/acre	1,468	1,588	1,554

Milk yields at Bridget's, 1968

	Low	Stocking rate High	
Cows grazed/acre	2.5	3.0	3.0
Concentrates lb/cow/day	2	2	6
Milk yield gal/acre	1,230	1,566	1,635

Milk yields at both farms showed an improvement over the previous year. At the increased stocking rate of $2\frac{1}{2}$ cows per acre at Trawscoed, the barley fed group produced more milk than the non-supplemented group. The same trend was noticed with the highest stocking rate at Bridget's, where the group receiving extra concentrates produced more milk than the other treatments. At neither farm was the feeding of concentrates profitable.

In 1969 the spring was very late and at Trawscoed the limit of stocking was reached at $2\frac{1}{2}$ cows per acre without supplementary feed. Similarly at Bridget's to maintain 3 cows per acre extra concentrates had to be fed. However, over 1,200 gallons of milk were produced per acre at Trawscoed without supplementary feed. At the lowest level of supplementary feeding (7.9 cwt barley per cow whilst at grass) 1,500 gallons of milk were produced per acre at Bridget's.

Throughout the trials, production has been steadily increased each year by using higher stocking rates. High nitrogen usage has been an important aspect of the trials, and up to 400 units of nitrogen have been applied as normal practice. The results suggest that concentrate feeding to spring calving cows at grass will only be profitable where stocking rates exceed those normally practised or in an abnormal season when grass is very short. During three years at Trawscoed, no extra milk was produced by the herd transferred onto aftermath grazings, and there were a number of management problems arising. For example, where a late silage crop was taken from the early grazed area in September 1968, there was considerable winter kill. This resulted in low sward vitality in the following spring, so that concentrate feeding was necessary to supplement the pasture until late May. The optimum management of an alternate grazing and cutting regime is not yet clearly defined.

At Trawscoed the butterfats and total solids have been rather low for the first three months at pasture, and in future it is intended to offer straw *ad lib.* to the cows in an effort to overcome this problem. At Bridget's, straw has always been on offer and the milk quality has been acceptable.

Output per acre is important but in these investigations production per acre has been quoted only for the period at grass. The total lactation output will be investigated in other trials, and already there are some indications at Trawscoed that January and February calving cows are more profitable than April calving cows. If milk production could be obtained in late winter without detriment to the utilization of cheap summer grass, better overall use of resources would be achieved. Further trials are therefore being carried out to determine whether longer lactations and higher lactation yields can be achieved by January and February calving.

RECENT EXPERIMENTS ON CALF FEEDING SYSTEMS

S. F. Clench, *Liscombe Experimental Husbandry Farm*

Since A. H. Adamson wrote *Calf Rearing* in Progress Report 1968, trials have continued at Boxworth, Bridget's, Gleadthorpe, Great House and Liscombe Experimental Husbandry Farms. The object has been to keep pace with continued developments in calf rearing with the ultimate aim of incorporating the results of investigations into a 'very simple early weaning system'. This, when sufficient experimental data is to hand, will probably involve low fat milk powder re-constituted in cold water, offered once per day to calves abruptly weaned at a concentrate intake of 1 lb per head per day. This low cost simple system could then be compared with systems currently giving acceptable results. The full effects of the rearing system being followed through for as long a period of the calves' lives as possible.

ONCE VERSUS TWICE A DAY FEEDING

Recent experiments carried out at Bridget's, Gleadthorpe, High Mowthorpe and Liscombe have confirmed results obtained elsewhere, that there is no difference in performance between calves fed once or twice daily on high (18 per cent) or low (4 per cent) fat milk substitutes whether mixed in warm or cold water. At three of the farms calves were individually penned indoors. The other farm used group rearing techniques both inside and at pasture. The milk substitute was fed at the rate of either $\frac{3}{4}$ or 1 lb of dry powder re-constituted in 4 or 5 pints of warm (37·8°C, 100°F) or cold (tap) water. Few difficulties were encountered in persuading the calves to accept the cold milk substitute, except on one occasion during very cold weather in February. High Mowthorpe reported that five pints of a liquid mix at one feed appeared to be the upper limit which could readily be taken by smaller calves. For all centres and treatments, the mean liveweight gain from arrival to 12 weeks of age varied from 1·10 to 1·54 lb per head per day and total concentrate consumption from 245 to 300 lb. The individually penned calves fed once per day showed a tendency to eat slightly more concentrate before weaning and were weaned 3 to 4 days earlier than their twice daily fed counterparts. Hereford x Friesian calves weighing 95 lb, group reared in January and February at Liscombe and fed cold milk once daily, were very slow to start growing and required 45 days to reach a weaning weight of 135 lb. This was 6 days longer than calves fed twice daily. Overall liveweight gains to 12 weeks of age, however, were very similar. All centres reported that once daily feeding did not adversely affect general health. Where calves were followed through to 25 weeks or longer after arrival, liveweight performance was satisfactory for all treatments.

WEANING AT A CONCENTRATE INTAKE OF 1 OR 2 LB PER DAY

Experiments are in progress at Boxworth, Gleadthorpe, Bridget's and High Mowthorpe comparing the performance of calves weaned at a solid con-

concentrate intake of 1 or 2 lb per day, following the feeding of either warm or cold milk substitute once daily. Boxworth and Bridgets are feeding 1 lb of dry powder re-constituted in 4 pints of cold water; Gleadthorpe are feeding the same quantity of milk powder but feeding it warm, their cold milk feeding trials having been abandoned. This was because of the very severe weather conditions they encountered in February (5.6°C , 22°F), during which time many of the calves offered cold milk refused to drink until some warm water was added. Scour problems were also encountered during this period. Points of detail which may influence once a day feeding, such as quantity of milk powder and volume of liquid fed are being further examined at High Mowthorpe where they are feeding $\frac{3}{4}$ lb of milk powder in either 3 or 5 pints of warm water. Preliminary results at Boxworth, Gleadthorpe and High Mowthorpe have shown no significant difference in the liveweight performance to 12 weeks of age between calves weaned at an individual solid concentrate intake of 1 or 2 lb. Weaning at a concentrate intake of 1 lb per day significantly reduced the period of liquid feeding by 8 to 10 days, but liveweights at weaning were significantly lower. High Mowthorpe again reported that 5 out of 18 calves which were offered 5 pints of milk substitute once daily, had difficulty at times in drinking this volume of liquid. The final results of this series of trials are not yet available.

REDUCING LABOUR IN GROUP REARING

Current investigations at Liscombe are concerned with reducing the peak labour demand during rearing, but still producing strong healthy calves at 12 weeks of age suitable for semi-intensive systems of grass beef production. All rearing systems use group penning, the calves being reared in batches of 10 to 20.

The first observation trials compared calves fed twice daily by bucket, calves reared on an automatic (Nursette) calf rearing machine, and calves fed dry milk substitute from troughs. Mean liveweight gains from arrival to 12 weeks of age were similar for twice daily and automatic feeding at 1.5 lb per head per day. However, as would be expected the automatic feeding system used a greater amount of milk powder (37 lb per calf) than did the twice daily bucket system (24 lb per calf), but peak labour demand was considerably reduced by automatic feeding. Feeding milk substitute dry proved unsuitable for calves (Hereford cross and Friesian steers) weighing less than 120 lb, and would seem suitable only where large calves are purchased which are probably 3 to $3\frac{1}{2}$ weeks old and where some milk powder is considered necessary to supplement dry concentrate feed.

January and February born Hereford x Friesian steer calves, and July born Devon x Friesian heifers reared at pasture formed the second series of trials. Twice daily bucket feeding was compared with *ad lib.* cold milk feeding and liquid feeding for $5\frac{1}{2}$ days only (i.e., no milk substitute being fed after the Saturday morning feed until Monday morning but early weaning concentrate hay and water being available at all times). All rearing systems produced satisfactory calves and no difference was detected between treatments at 12 weeks or at 9 months of age. There was no marked difference in health between systems although there was a tendency for a higher incidence of scour on the *ad lib.* cold milk treatments. A high level of stockmanship is

needed to distinguish between the calf that is 'loose' but otherwise healthy, and the animal that is scouring and off colour. The changeover period to fully unrestricted feeding is the time when scouring problems are most likely to occur.

As preliminary cold milk feeding trials produced satisfactory liveweight gains to 12 weeks of age and did not use excessive quantities of expensive milk powder (27 to 35 lb per calf), further trials comparing automatic (Nursette) feeding with *ad lib.* cold milk feeding were initiated. Could the saving of labour experienced with the automatic feeding machines be gained with the low capital cost of *ad lib.* cold milk feeding? With this system, the supply of milk is taken from milk churns through cheap plastic pipes and teats. Friesian steer calves penned in groups of 10, inside the calf house, or outside in an open-sided shed were reared on 2 automatic feeding machines. These were compared with a similar group of animals penned inside and fed *ad lib.* cold milk from a churn. Liveweight gains to 12 weeks of age varied from 1.1 to 1.4 lb per head per day for all groups of calves, but total consumption of milk powder rose sharply to 51 to 57 lb per calf. Both methods of *ad lib.* feeding produced satisfactory animals, although overall performance was lower than normal due to a bad outbreak of virus pneumonia. More scour problems were encountered on both systems of *ad lib.* feeding than are normally associated with twice daily bucket feeding. The calves fed cold milk performed at least as well as those reared on the automatic rearing machines with no more labour and no machine cost. Further investigations into the technique of cold milk rearing, and the effects of abrupt or gradual weaning on calves fed *ad lib.* milk are at present being undertaken.

COLOSTRUM FOR CALF REARING

Trials at Great House have examined the effect of withholding the first feed of colostrum from newly born calves for different periods of time. These showed that if colostrum was withheld for longer than 9 hours after birth, the chances of the calf absorbing the necessary antibodies into its bloodstream were much reduced.

Bridget's are investigating the use of colostrum for extended periods of calf feeding. Twelve to thirteen gallons of colostrum are produced by the Friesian cow in the four days after calving. Is this sufficient to provide for the liquid feeding phase of the calf's life? In observation studies, dairy heifer calves have been fed fresh or stale colostrum from birth to weaning, colostrum for the first 14 days of life followed by milk substitute to weaning, or colostrum and milk substitute fed alternate weeks from birth to weaning.

From these observations it would appear that untreated colostrum can be kept even in hot weather for long enough to cover the liquid-feeding period of a replacement heifer calf, merely by allowing it to sour naturally in a churn. It quickly attains a yogurt-like consistency after which it does not apparently deteriorate further, and remains quite acceptable to the calves. Batches of colostrum have been kept in this way for up to 100 days, so that expensive forms of preservation may prove unnecessary if this technique continues to prove satisfactory. Calves fed stale colostrum appeared to be ready for weaning at a concentrate intake of 2 lb per head per day, and

earlier than when fed either fresh frozen colostrum alone or in combination with milk substitute. No ill health, scouring or looseness has been observed with colostrum fed calves, even when switched abruptly to milk substitute. Trials are continuing with the hope that a satisfactory system of using colostrum, when available, for rearing dairy heifer replacements can be evolved.

CALF HOUSING

M. B. Helps, *High Mowthorpe Experimental Husbandry Farm*

Calves for many beef units are purchased at 7 to 14 days old. For these young calves the change in ownership often results in stresses from travelling, mixing and crowding with other calves, as well as a change in diet. In these circumstances housing conditions may affect the health, comfort and subsequent performance of the calves.

Many trials have been conducted by N.A.A.S. and others, which have compared calf houses by various types but there is a lack of information which defines the ideal environment for young calves in terms of temperature, ventilation rate or humidity. In an effort to provide some of this information, Drayton and High Mowthorpe were equipped with specialized environment houses as described in the ninth Progress Report (1968). Each house provides accommodation for 60 calves in five compartments, and each compartment contains 12 individual calf-pens. Four of the compartments are fully insulated and equipped with controlled forced ventilation systems and supplementary heaters. The fifth is naturally ventilated.

All the calves taken into these houses so far have been Friesian and Hereford x Friesian bull calves purchased at 7 to 14 days old at an average liveweight of about 100 lb. They have all been destined for semi-intensive beef systems and reared on an early weaning system. In all intakes the calves have been kept in the environment house for the first eight weeks after purchase.

TEMPERATURE

During the first winter of operations with these specialized buildings (1967/68) trials were carried out on the effect of temperature on the health and performance of young calves. The results of these trials supported the limited evidence already available from other sources that although the temperature in a calf house should not fall below 12·8°C (55°F) in early life, by the time a calf is three weeks old it should be able to live and grow satisfactorily in temperatures down to 8°C (46°F).

VENTILATION RATE

Many rearers are of the opinion that a high rate of artificial ventilation minimises respiratory infections. This was one of the reasons why it was decided to look at the effect of varying ventilation rates in the calf houses in the winter of 1968/69.

Intakes of 60 calves were made at Drayton and High Mowthorpe in September, November and February with a further intake at Drayton

only in April. Details of the ventilation treatments compared are given below.

Ventilation Treatments

Per calf cfm	Air changes per hour
20	4.7
42	9.8
68	15.9
100	23.4
Natural ventilation	variable

Temperatures in the artificially ventilated compartments were generally maintained within the range 15.6°C to 18.4°C, (60 to 65°F) although on some occasions at high ventilation rates and in very cold weather temperatures fell below this range. In the naturally ventilated compartments temperatures depended on external conditions.

In all ventilation treatments the environment stayed fresh for the first four or five weeks, but from then on the lowest ventilation rate produced a damp stuffy atmosphere with a definite smell of ammonia. Condensation tended to occur at the lowest ventilation rate after five weeks. In some intakes it also appeared in the house ventilated at 42 cfm per calf towards the end of the eight week experimental period. Whenever it occurred the amount and frequency of condensation was related to external temperatures.

The average daily liveweight gains on each treatment meaned over the winter period are set out below for each farm.

D.L.W.G. meaned over winter period, lb

Ventilation rate cfm/calf	0-3 weeks	0-5 weeks	0-8 weeks
Drayton (4 Intakes)			
20	0.26	0.64	1.05
42	0.30	0.74	1.10
68	0.46	0.84	1.26
100	0.31	0.72	1.14
Natural ventilation	0.40	0.83	1.22
High Mowthorpe (Sept. and Feb. intakes only)			
20	0.90	1.11	1.31
42	0.77	0.98	1.26
68	0.73	1.02	1.30
100	0.75	1.47	1.22
Natural ventilation	0.70	1.43	1.27

At Drayton, over the winter as a whole, slightly better results have been obtained under the 68 cfm per calf ventilation rate and the naturally ventilated regime than under the other rates of artificial ventilation. The mean results do not suggest that the relative liveweight gains under the different ventilation rates changed during the treatment period. At High Mowthorpe the differences between ventilation rates were smaller and it is difficult to draw any firm conclusions on the optimum rate of artificial ventilation. Most of the small differences in liveweight gain that existed between treatments were related to differences in the quantity of concentrates consumed.

The table below shows concentrate consumption per calf at each farm and relates concentrate consumption and liveweight gain at the four controlled levels of ventilation to the performance of the calves in natural ventilation.

Mean concentrate consumption 0-8 weeks, lb.

Ventilation rate cfm/calf	Consumption		D.L.W.G. 0-8 weeks as per cent natural ventilation
	lb/head	as per cent natural ventilation	
Drayton (4 intakes)			
20	130	86	86
42	132	87	89
68	148	98	103
100	139	92	93
Natural ventilation	151	100	100
High Mowthorpe (Sept. and Feb. intakes only)			
20	155	106	103
42	141	97	95
68	147	101	102
100	136	93	96
Natural ventilation	146	100	100

With the exception of the 68 cfm per calf treatment at Drayton the gains were closely related to food consumption. Although these figures show that concentrate consumption has been the major influence on liveweight gain this does not imply that ventilation rate is unimportant. An environment that encourages calves to eat would have value in itself provided food conversion efficiency was unimpaired.

The records kept of mortality and medication gave no positive evidence that the ventilation rates used affected the health of the calves whilst they were on the experiment.

PRACTICAL IMPLICATIONS

The work described relates specifically to purchased calves reared for beef production which were approximately 10 days old when purchased. The

results of the work suggest that for most of the year the amount of extra warmth required by the calves is negligible. Healthy calves in a dry, draught free building seem relatively insensitive to temperature, certainly after 3 weeks of age, so the rearer need not incur the cost of providing a well insulated building to conserve heat or permanent equipment to supply heat to the whole house. Localized warmth provided with an infra red lamp will suffice for the short time it is needed for the odd sick or very young calf.

If the calf house has adequate cubic capacity or air space (450–500 cu.ft/calf) such as would be provided if calf pens were erected under a protected Dutch barn or cattle yard, then good natural ventilation will suffice. As air space available falls below this there will come a stage when artificial ventilation becomes necessary.

The artificial ventilation in the trials described here took place in compartments providing 256 cu. ft of air space per calf. In these conditions there was some evidence that artificial ventilation at about 68 cfm per calf was desirable, particularly after the calves reached 6 weeks of age.

FEEDING DRIED POULTRY WASTE TO BEEF CATTLE

J. M. Oliphant, *Boxworth Experimental Husbandry Farm*

There has been a great deal of interest over the past two years in the recycling of poultry waste through the ruminant. This interest has been exhibited not only by farmers, but also by the smaller compounders of feeding stuffs. Dried poultry waste is a very cheap source of protein for the ruminant, containing as it does large quantities of nitrogenous compounds. It is available, (as yet in fairly limited amounts), in two forms; either from deep litter houses, in which case it has an admixture of wood shavings, or in a purer form from laying batteries. These contain approximately 26 per cent and 36 per cent crude protein in the dry matter respectively.

Experiments were started at Boxworth and Drayton E.H.Fs. at the beginning of 1969 using poultry waste as an alternative source of protein ingredient in rations for intensive beef. Treatment rations were:

- a 'Rowett' type barley beef mixture which acted as control;
- a mixture in which normal protein constituents were replaced entirely by poultry waste;
- a mixture in which half the normal protein constituents were replaced by poultry waste.

Identical poultry waste of the deep litter type was fed in pelleted form at each centre and treatment rations were very similar. There were made up as follows:

Drayton

	Control	Poultry waste	Mixture
Rolled barley (cwt)	17.1	15	16
Protein/mineral supplement (cwt)	2.9	—	1.5
Poultry waste (cwt)	—	5	2.5
Vitamin supplement (lb)	—	5	2.5

Boxworth

	Control	Poultry waste	Mixture
Rolled barley (cwt)	17.5	14.25	15.75
Soya meal (cwt)	1.5	—	0.75
Fish meal (cwt)	0.5	—	0.25
Poultry waste (cwt)	—	5.5	2.75
Vitamin supplement (lb)	20	20	20
Mineral supplement (lb)	30	—	15

As far as was possible, rations were of equivalent crude protein content and an attempt was made to minimise the protein derived from the barley in order to make the best possible evaluation of the poultry waste. Following the 1968 harvest, low protein barleys were difficult to come by, but Drayton started the trial with barley of only 8.6 per cent crude protein and Boxworth managed to maintain a supply of 10 per cent barley until almost the very end.

At Boxworth two groups of four animals were allocated to each treatment: Drayton had six individually fed beasts on each treatment. Friesian steer calves, born in the autumn of 1968 were used at both farms.

Before the poultry waste was fed, analysis confirmed that it was free from harmful organisms such as *Salmonella*, and antibiotic residues. These and previous samples of the material showed that it contained adequate quantities of minerals, with only sodium on a possibly marginal level, therefore no minerals were fed on the all poultry waste treatments.

At both stations there was a tendency to refuse the poultry waste and, being in pelleted form, it was easier for the animals to select the barley and leave initially a greater concentration of pellets in the remaining food. Refusal was not absolute however, since the pellets would eventually be consumed, but some other form of the material might give better results. As a meal it would probably be too fine, although the manufacturer now includes a small quantity of fish oil to prevent dustiness.

Results from both stations show similar trends and these are summarized in the table below:

	Drayton			Boxworth		
	Control	Poultry waste	Mixture	Control	Poultry waste	Mixture
Initial liveweight (lb)	299	290	292	273	273	273
Slaughter weight (lb)	861	851	861	877	872	869
Days on trial	190	238	202	241	291	254
D.L.W.G. (lb)	2.96	2.35	2.81	2.51	2.06	2.35
Total concentrate (cwt)	28.2	36.8	33.0	31.0	35.8	32.3
lb concs/lb L.W.G.	5.6	7.4	6.5	5.7	6.7	6.1
Carcass weight (lb)	475	476	482	485	472	477
K.O. per cent	55.1	55.9	56.0	55.3	54.1	54.9
Grade	A-/A	A	A-/A	A-	B	B+

The available energy value of poultry waste is not at present accurately known but is, in any case, very low. Since it replaced an appreciable quantity of barley in the treatment rations, this clearly reduced the energy level of the rations and this was reflected in animal performance. The results showed

that it took the cattle on the full poultry waste supplement seven weeks longer to reach the same slaughter weight (475 lb dead weight), and those on the half poultry waste about ten days longer. For this reason more food was consumed by the groups receiving poultry waste. Liveweight gain varied with the quantity of poultry waste introduced into the ration. Thus with the ration containing all poultry waste, performance was reduced by 0.5 to 0.6 lb per day liveweight gain compared with the control. The mixture ration occupied an intermediate position between the two.

The financial results are summarized below:

	Drayton			Boxworth		
	Control	Poultry waste	Mixture	Control	Poultry waste	Mixture
Av. return at sale	£87.15	88.75	88.75	87.82	85.55	84.84
Calf subsidy	£11.25	11.25	11.25	11.25	11.25	11.25
Total A	£98.40	100.00	100.00	99.07	96.80	96.09
Cost of calf (A-B)	£33.0	33.0	33.0	35.5	35.5	35.5
Concentrates	£39.9	40.0	41.2	43.7	38.7	40.0
Total B	£72.9	73.0	74.2	79.2	74.2	75.5
Margin over cost of calf and concs. (A-B)	£25.5	27.0	25.8	19.9	22.6	20.6
Cost of concs/lb L.W.G.	17.1d	17.1d	17.4d	17.4d	15.5d	16.1d
Cost/ton of concs.	£28.5	21.3	25.0	28.25	21.55	24.77

In both experiments the feeding of poultry waste resulted in an increase in the margin and the effect was greater at Boxworth than at Drayton. At the latter no saving in food cost was obtained from poultry waste due to the extra time taken to finish and the increased margin over the control seems to have been the result of the better price obtained for the carcass.

At Boxworth, however, a greater comparative margin was obtained from the poultry waste treatments despite a similar amount of extra time taken to reach finishing weight and the lower price obtained for the carcass. This was the result of the substitution of poultry waste for normal protein in the ration which resulted in a saving in food cost of £5 per beast.

The results reported were derived from relatively small scale experiments in one season only. Further work is in progress which may in due course modify the conclusions drawn above.

NEW BREEDS AND CROSSES OF SHEEP

J. S. Broadbent, *N.A.A.S. Sheep Specialist, Skipton*

Over the last few years in the sheep industry there has been a growing interest in the development of new breeds and crosses of sheep better able to meet the challenge of economic circumstances than some of our existing breeds. The search for genetic material with something to contribute to

new breeds has extended overseas to Finland, Germany, Holland and France. Importations have been made from these countries both by breeding companies and by individual farmers.

On the E.H.Fs. we have had a number of new breeds and crosses of sheep, some containing imported blood. These have served a two fold purpose. They have demonstrated the new breeds to farmers, and have at the same time provided information on their advantages and disadvantages under conditions where they could be compared with standard breeds or crosses in the same environment.

At Trawscoed two such trials are in progress. The first of these is a comparison of 24 TC.1 (Colbred x Clun) ewes with 24 Welsh Halfbred (Border Leicester x Welsh) ewes. These sheep were obtained in 1966 and have been compared for fat lamb production over the past three years. The pattern emerging from these results shows the TC.1 ewes to be more prolific, and the lambs to be slightly quicker growing than the Welsh Halfbreds. In the past two years the TC.1 ewes have produced on average, 37 lambs from 23 ewes (161 per cent) at weaning, compared with 29 lambs from 22 Welsh Halfbred ewes (134 per cent) at weaning. Lamb growth rates averaged 0.52 and 0.50 lb per head per day respectively. In the second trial at Trawscoed, three breeds of ram – the Border Leicester, the Border Leicester x Finnish Landrace and the Cadzow Improver – are being crossed with Welsh Mountain ewes to produce ewes which will be compared for fat lamb production. So far, the first crop of lambs has been taken from the crossbred ewes and it appears from this very limited evidence, that the Improver crosses have some advantage over the others in terms of prolificacy.

At High Mowthorpe two new crosses are being investigated. One of these, the Romney Halfbred (North Country Cheviot x Romney) is being compared with the standard Scottish Halfbred (Border Leicester x Cheviot) as a producer of fat lambs. After four years of trial, the average production in terms of lambs reared to weaning per ewe mated was 1.43 for the Romney Halfbreds and 1.58 for the Scottish Halfbreds. Birth weight of lambs slightly favoured the Romney Halfbreds, and wool production was very similar.

Also under scrutiny at High Mowthorpe is a group of 25 TC.3 (Colbred x North Country Cheviot) ewes. These were purchased in 1966 as ewe lambs which means that three lamb crops have now been obtained from them. After a good start when these sheep lambed at 12 months old and reared 1.08 lambs per ewe mated, performance has been rather disappointing; 1.36 and 1.50 lambs have been reared per ewe mated in the second and third years respectively.

In addition to the work mentioned, where new breeds of sheep are being looked at under good traditional systems, a more futuristic approach is being adopted with a trial at High Mowthorpe and Drayton. The trial is intended to look at ways and means of making a major breakthrough in terms of output from sheep. At both centres the Finnish Landrace, a breed with a very high level of prolificacy, is being incorporated into the system. At High Mowthorpe, the approach adopted is to explore twice yearly lambing, using light control, hormones and weaning the lambs at 24 hours of age. Several different crosses are being tried on this system. To date, January lambing has proved satisfactory whereas July lambing has proved more difficult, with only about half the ewes lambing. Obviously more

development work is needed if this is ever to form the basis of a workable system. At Drayton, the approach is rather different, with the Finnish Landrace ram being used on the existing Scottish Halfbred ewes to produce what should be large, highly prolific ewes. The objective of these cross bred ewes is a large litter of lambs once a year. Ewe lambs were produced in 1969 at Drayton, so this year should see the first lambs born from the crossbred ewes.

Another project which started last autumn at Drayton, Trawscoed and High Mowthorpe involves the multiplication and assessment of a new breed of sheep developed at Cambridge University. Sheep of various breeds, mainly British, have been used as foundation material, but all the ewes have one thing in common – an outstanding record of prolificacy which averages more than three lambs per lambing sustained over six or seven years. In this co-operative venture the sheep will be carefully recorded on the E.H.Fs. and the results will be computed centrally at Cambridge.

A further project involving the use of new breeds is taking place in association with the Animal Breeding Research Organisation. Finnish Landrace x Border Leicester rams have been used on commercial farms to produce cross bred ewes alongside contemporaries of standard breeds. The ewes are being evaluated both on commercial farms and on several of the E.H.Fs. as producers of fat lambs.

All these projects show the extent to which E.H.Fs. are committed to the evaluation of new breeds and crosses of sheep. This unbiased test bench should play an important part in providing information which could have far reaching effects on the pattern of development in the sheep industry over the next 10 or 20 years.

ARTIFICIAL REARING OF LAMBS

Miss B. A. Maund, *Drayton Experimental Husbandry Farm*

Artificial rearing of lambs on milk substitute has been developed as a possible means of solving some of the problems arising from increased prolificacy of ewes.

Three farms, Drayton, Great House and High Mowthorpe, have between them artificially reared more than 700 lambs over the last three years. At Drayton and High Mowthorpe, Finnish Landrace rams have been used to produce a more prolific cross bred ewe, and at High Mowthorpe this has been combined with increased frequency of lambing. If lambing percentages of hill sheep such as the Gritstone flock at Great House, are to be increased greater numbers of twins will be born. However, the performance of twins on the hill is inferior to that of single lambs. Consequently at Great House comparisons have been made between twin lambs born to a hill ewe, one of which was reared naturally and the other artificially.

Despite slightly differing objectives at each farm the same basic principles have been used.

METHODS OF REARING

Lambs are removed from the ewe at between 12 and 48 hours after birth. It is essential for the lamb to receive colostrum but experience from all farms confirms that the longer the lamb remains with the ewe the greater the difficulties are in teaching it to drink milk substitute.

Originally all farms were using a proprietary milk powder (30 per cent fat) reconstituted at the rate of 2 lb powder to 1 gal of cold water and fed *ad lib.* However, at High Mowthorpe comparisons have been made between 20 per cent fat milk substitute fed cold *ad lib.* with limited quantities fed twice a day either warm or cold.

Milk is dispensed either through specially designed liquid feeders or from buckets with self-sealing teats placed at lamb height. It is essential to have a system that does not require a great deal of effort by the lamb, otherwise it becomes discouraged before obtaining milk and ceases to suck. Teaching the lamb to suckle is the most difficult and time consuming period of all. At Drayton it has been estimated that at least two hours per lamb was needed, but this may have been due in part, to the type of equipment used; with gravity feeders it may be reduced. In the earlier trials cold milk was used during the training period. Latterly warm milk has been used successfully to encourage feeding, and once the lamb is suckling well cold milk can be introduced. Once lambs are feeding, few difficulties have been encountered although some scouring, probably due to over-feeding, occurs. Absolute cleanliness of all equipment is important to prevent milk souring, since sour milk limits intake.

Small quantities of fresh concentrates, hay and water are always available.

WEANING

The optimum time for weaning is still unresolved. Ideally this should be as late as possible since the conversion ratio whilst on milk is approximately 1 : 1. However milk substitute is the highest single cost and so it is essential to achieve a balance between overall performance and the quantity of milk substitute fed. The age at which weaning takes place obviously affects the quantity of milk consumed and age at weaning has varied from as little as 17 days at Drayton to 44 days at Great House. Trials at Drayton indicated that lighter and younger lambs of 18 to 21 lb had a greater ability to overcome the weaning check, compared with heavier 24 to 25 lb lambs. However this was not the experience at High Mowthorpe where lambs weaned at 21 days possibly had a lower resistance to an outbreak of *E. coli* than lambs weaned at 28 days. Weaning at 21 days, irrespective of weight, has been satisfactory at Great House. Abrupt or gradual weaning has also been investigated. Lambs consume only small quantities of concentrates whilst on *ad lib.* milk and this probably accounts for the check which occurs at weaning. Lambs gradually weaned ate more concentrates before weaning but not sufficient to prevent a check. There was, therefore, little to choose between either method.

Due to the various factors affecting weaning, the quantity of milk substitute fed has ranged from as little as 9 lb for lambs weaned at 21 days to over 30 lb for lambs weaned at 42 days. More usually the range has been

between 14 and 23 lb. The optimum probably lies at the lower end of this range, combined with some form of restricted feeding or gradual weaning in the 21 to 28 day period.

After weaning lambs have been fed early weaning pellets *ad lib.* to six or eight weeks.

PERFORMANCE AND COSTS

Daily liveweight gains from birth to weaning have ranged from 0.25 lb to 0.75 lb per day with an overall mean of 0.5 lb per day. Despite the weaning check, pre-and post-weaning liveweight gains were similar. It should therefore, be possible to attain a mean daily liveweight gain of 0.5 lb from birth to six or eight weeks.

Food costs from birth to 6 weeks at Drayton in 1969 were:

14 lb milk substitute	£1. 2. 0.
20 lb early weaning pellets	5. 6.
	£1. 9. 6

These figures agree well with those from High Mowthorpe where the food costs from birth to eight weeks are estimated to range from £1. 7s. to £2. 5s., according to the quantity of milk substitute fed.

MORTALITY AND DISEASE

Where there have been no specific disease problems the mortality in lambs removed from the ewe specifically for artificial rearing has varied between 8 and 12 per cent. However, with orphaned, abandoned or mismothered lambs, the mortality has been as high as 35–42 per cent, showing that this system is not for the poor, weakly lambs.

Deaths amongst the younger lambs have occurred from a variety of causes such as general weakness, scour, bloat, pneumonia, etc. However serious losses have occurred in slightly older lambs from *E. coli* infection and coccidiosis. The latter has been particularly troublesome, but when necessary outbreaks have been successfully treated with sulphadiazine.

POST WEANING PERFORMANCE

Difficulties have arisen when turning artificially reared lambs out to grass. It is imperative that the lambs go on to clean pasture, but even so outbreaks of coccidiosis have occurred.

Attention is now turning towards indoor fattening. In this case the lambs have remained indoors and the early weaning pellets have been gradually replaced with a cheaper barley based mix. A trial conducted at Drayton in 1969 showed that lambs consumed 200 lb concentrates from six weeks of age to slaughter at a mean weight of 76 lb at 15 weeks. The cost of this food was £3. 5s. with an overall conversion of 4.4 : 1. These figures are similar to those from High Mowthorpe and Great House where food costs for this period were in the range of £2. 10s. to £4. 4s.

Daily liveweight gains of 0.5—0.6 lb per day can be expected. Total food costs for lambs on a barley and pellet ration at Drayton and High Mowthorpe worked out at 34d per lb carcass weight. It is unlikely that these costs would vary much over the year, the price of barley being the most variable factor. Thus to obtain maximum margin over food costs marketing must coincide with the highest realisation prices.

Deaths have occurred during the fattening period from copper poisoning since copper is not excreted but stored in the liver. Thus it is important to have a ration as low in copper as possible. Other deaths have occurred from pneumonia and coccidiosis.

At Drayton and High Mowthorpe the carcasses were perfectly acceptable to the butcher but at Great House lambs on the intensive diet lacked conformation.

Killing out percentages at 42—45 per cent were slightly lower than for naturally reared lambs.

CONCLUSIONS

Artificial rearing and indoor fattening of lambs is a high cost system. The only justification for this system will be where a high return can be obtained for the lamb, where a prolific ewe is used and rears some of the lambs naturally, or where there is increased frequency of lambing.

The work to date has shown that artificial rearing of lambs is a practical proposition, but further work is required to develop a more economic system.

FATTENING STORE LAMBS ON CLOVER

J. M. Rablah, *Drayton Experimental Husbandry Farm*

Increasing stocking rates and nitrogen usage often result in more store lambs in the autumn. These lambs can be sold, fattened on crops grown for the purpose, or finished indoors. Alternatively, they can be used to clear up the autumn flush of grass which remains when cattle are housed, but which under systems of high nitrogen usage, is unlikely to contain clover.

To assess the value of clover for fattening store lambs a sward containing red clover was compared with a perennial ryegrass sward. In the two years of the trial the growth rate of the lambs from mid-September to early November was 25 per cent and 10 per cent better on the clover sward than on the grass sward. Supplementation with rolled barley was of no value up to this stage and in fact depressed growth rates. In the second year the trial continued until mid-December and in the last four weeks the group on clover without supplementation made gains of about $1\frac{1}{2}$ lb per week. However there was some indication that once the quality of the grazing deteriorated (e.g., after a sharp frost) feeding barley helped to maintain growth rates and improve carcass quality and killing out percentage on the grass sward.

PROTEIN IN RATIONS FOR IN-LAMB HILL EWES

R. I. W. A. Richards, *Pwllpeiran Experimental Husbandry Farm*

A trial on the supplementary feeding of 3, 4 and 5 year old speckle-faced Welsh Mountain ewes was initiated at Pwllpeiran E.H.F. in 1967 to compare different levels and sources of protein. In this trial non-protein nitrogen in the form of urea was compared with a mixture of vegetable proteins. The treatments were:

10 per cent crude protein	=	100 parts cereal mix (25 parts barley meal, 50 parts maize meal, 25 parts sugar beet pulp)
13 per cent crude protein	=	88 parts cereal mix + 12 parts vegetable protein mix
13 per cent crude protein	=	98.6 parts cereal mix + 1.4 parts urea
16 per cent crude protein	=	77.6 parts cereal mix + 22.4 parts vegetable protein mix
16 per cent crude protein	=	87.6 parts cereal mix + 11.1 parts vegetable protein mix and 1.3 parts urea.

Urea contains approximately 45 per cent nitrogen which makes it theoretically equivalent to a crude protein content of 280 per cent and therefore only a very small quantity is required to raise the crude protein level of a ration from 10 to 13 per cent. Urea can be toxic if fed in quantities above 3 per cent of the total ration and therefore extreme care must be taken to ensure that the very small quantity required is thoroughly mixed throughout the much larger bulk of the cereals part of the ration. To ensure a thorough mix, the 1.4 parts of urea used in this trial were mixed initially with 20 parts of cereals and this mixture was then thoroughly mixed with the bulk of the cereals.

The vegetable protein component of the above rations was made up of equal parts of cotton cake, decorticated ground nut meal and soya bean meal. The 3, 4 and 5 year old ewes which had been mated to a Teeswater tup were allocated to the treatments according to live weight and age at tupping. All the ewes had similar management throughout the previous twelve months and grazed the same area during the experimental period. They were collected and sorted every day for feeding and the supplements were given for the last 6½ weeks of pregnancy, the rate of feeding being increased gradually to a maximum of 8 oz per head per day.

Results (lb) 1967-69

	10 per cent cereals	13 per cent veg. protein	13 per cent urea	16 per cent veg. protein	16 per cent urea and veg. protein
October weight	76.6	76.0	76.1	75.8	76.4
July weight	76.9	77.0	75.6	76.5	77.3
Wool weight	2.39	2.52	2.48	2.42	2.46
Lamb birth weight	8.1	8.1	8.2	7.9	8.2
Lamb weight at 17 wks	63.5	61.8	64.3	63.4	64.4
Lambing per cent (excluding true barrens)	108.2	111.8	110.8	106.7	105.6
Feeding cost/ewe	5s. 11d	6s. 5d	6s. 0d	6s. 8d	6s. 4d

The three year mean results show that the optimum level of crude protein in the supplementary feed of 3, 4 and 5 year old ewes is around 13 per cent. These findings are in agreement with the 5 year mean results of the supplementary feeding experiment with two year old ewes, where the 12 per cent level of crude protein gave the best economic return.

Lamb birth weights on all treatments were very similar, as were lamb weights at 17 weeks of age. The lambing percentage (excluding true barrenness) of the 13 per cent crude protein treatments was superior to all other treatments. Furthermore, it is interesting to note that the lambing percentage (excluding true barrenness) of the 10 per cent crude protein treatment is superior to that of the two treatments with the higher level of crude protein.

When the total live weight of lamb produced per 100 ewes was related to the cost of supplementary feeding, the results showed definitely that there was no advantage in feeding supplements containing more than 13 per cent crude protein. Furthermore, the results showed that non-protein nitrogen in the form of urea, because of its relative cheapness, gave a better return per unit of feed cost than vegetable protein.

Bearing in mind the importance of keeping down the cost of production, and that only a small amount of protein supplement over and above that supplied by the cereal part of the ration seems to be required to attain the optimum results, it would appear that for in-lamb ewes this can be supplied in the form of urea.

FIELD BEANS IN RATIONS FOR LAYING HENS

R. Hardy, *Gleadthorpe Experimental Husbandry Farm*

The search for a suitable break crop to stem the decline in the yield of continuously grown cereals has led to a renewed interest in field beans. Encouraged by a Government grant of £5 per acre, the bean acreage in England and Wales has expanded rapidly in recent years. With this increase in bean production has come a demand for information about possible feeding outlets for the crop.

Beans have been a very popular feed for beef cattle of all ages and their value in rations for dairy cows and pigs is well known. However, experience of feeding beans to poultry is more limited. A number of egg producers have been including small quantities of beans in poultry rations with apparent success but it was felt that more scientifically-based information was required. A trial was therefore started at Gleadthorpe E.H.F. in 1968 to investigate the value of including beans in layers rations.

From a home mixed ration containing wheat, barley, fishmeal, soya bean meal, minerals and vitamins, two modified rations containing 10 per cent and 20 per cent field beans were devised by substituting 1 cwt of field beans for $\frac{1}{2}$ cwt of soya bean meal plus $\frac{1}{2}$ cwt of barley. All rations were designed to have similar energy, crude protein and mineral levels together with balanced amounts of the important amino acids. As maize or grass meal was not included in the rations, a yolk colourant was added to the diets. The rations are being fed to light and medium laying strains housed in battery cages.

Egg production and grading data for the first trial are now available. Differences in egg production per bird were small but a trend in egg grading was apparent. Birds fed increasing quantities of beans produced progressively more eggs in the medium and small grades, with a consequent reduction in the number falling in the large grade compared to those fed bean free diets.

The completion of a further two trials will enable firmer conclusions to be drawn on the effects of feeding beans to laying birds.

As a result of the findings from the first trial, investigations have begun to determine the factors which may be responsible for reducing egg size in rations containing field beans.

Fruit

THE CHANGING SCENE IN FRUIT VARIETY TRIALS

J. M. S. Potter, *National Fruit Trials*

The testing of new varieties of all kinds of hardy fruits has assumed considerable importance during the last decade and interest in the commercial potential of anything new is now greater than it has ever been.

The reason for this is that the fruit growing industry is facing an ever increasing competitive situation which will become more acute if we join the European Economic Community. If apple production in particular is to remain viable, yields of new varieties will have to be considerably in excess of older ones. To give an example, the yield from a modern orchard of Cox's Orange Pippin is in the region of 600 bushels per acre, whereas the yield of a modern planting of Golden Delicious in France does not often fall below 1,000 bushels per acre and is sometimes higher. Another factor which has increased the urgency of variety testing is the increased breeding programme in this country which means that a rapidly growing number of breeders' selections are now being submitted for trial. Two or three decades ago the vast majority of new fruit varieties either came from nurserymen or amateurs, and very few from our research stations other than those concerned with breeding strawberries and raspberries. The present position is the complete reverse, with practically nothing being received from the nurseryman and amateur and an ever increasing flow from the professional breeder.

One of the problems in testing new varieties of tree fruits in the past was the time required to determine whether the new selection had any commercial merit, and it was not uncommon for a period of twenty years to elapse before a decision could be reached. However, circumstances have completely changed, and with the application of modern techniques results can be obtained in half or even less of the time it required twenty or thirty years ago. Furthermore the experience gained in breeding is now permitting the raiser to make his selections, even with a genetically complex species such as the apple, at a much earlier stage than was considered possible twenty years ago. To give an example, certain characters of the seedling apple indicate that it may come into bearing early or late, and will produce large or small fruits. These and other characters permit an early selection or elimination of seedlings even before they have fruited.

Seedling apples from particular progenies may fruit within three or four years of germination, and the National Fruit Trials already has included in a trial a seedling apple which was raised at East Malling Research Station as recently as 1965. Assuming that this seedling continues to show commercial merit, there is no reason to suppose that it could not be finding its own level in the field twelve and no more than fifteen years from the time the seed was sown. Twenty years ago this would have been considered impossible.

For their field testing, new selections are put through screening trials to determine as quickly as possible if they have any real pomological merit to make them suitable for planting commercially, and the life of any trial of apple, pear or plum is limited to ten years. The first two or three years are

concerned with building up a tree, although pruning at this stage is relatively light, and a five to six year cropping period is sufficient to determine the potential cropping and general fruit characters of any new seedling.

When planting a trial, standard commercial varieties are included in order to provide a yardstick against which the performance of others can be measured. The characters looked for are regularity of cropping which must be consistent with heavy yield, combined with good commercial size and market characters such as firmness and general eye appeal. In other words a very high standard is set for any unnamed selection, and it would be true to say that if 2 per cent showed commercial promise this would be considered sufficiently rewarding to compensate for the many other negative results. The number of breeders' unnamed selections being submitted for trial is increasing year by year, and there is no doubt that by testing very large numbers sooner or later much improved varieties will be found.

There is still doubt in some growers minds about how quickly results can be obtained. The National Fruit Trials took over Brogdale Farm in 1952-53 and the first apple trial was planted the following winter (1953-54). This comprised over 90 new apples, 14 of which had been obtained from Japan. Cropping started in 1958 and by 1961 the yield from the Japanese apple Mutsu had been so outstanding that growers were already making arrangements to plant it. Fruit from commercial holdings was being marketed by 1967 and at that time there was some market resistance to the name Mutsu. Because of this it was agreed to use the name Crispin as a commercial synonym. Experience with this variety indicates that there is no reason at all why a new apple should not be found cropping in growers' first test plantings in their own orchards twelve to fifteen years after raising, or ten years or less after planting in a trial. When a new variety has all the desirable characters, the name selected for it is going to be of considerable importance and thought will have to be given to the selection of names which, if possible, highlight the good selling points of the fruit.

There has been quite a tradition of soft fruit breeding at Research Institutes in this country, Mr. R. D. Reid, at Auchincruive, having produced new strawberry varieties, the late Mr. N. H. Grubb at East Malling worked on raspberries and Mr. G. T. Spinks of Long Ashton on black currants. This breeding work is being continued by their successors and others and necessitates a continuing programme of variety testing at the National Fruit Trials. Screening trials of strawberries, raspberries and black currants are in progress at Brogdale and are followed by performance trials at Experimental Horticultural Stations. For strawberries the co-operating stations are Efford, Kirton and Rosewarne. With this crop, young plants of each of the most promising varieties in the trial are re-propagated during the first season of the screening trial so that as soon as a preliminary assessment of the varieties has been made planting material is available for extended performance trial at the E. H. Stations. The first of these is just being completed at Efford, Kirton and Rosewarne having given some valuable results. Further similar trials will be planted at the Experimental Horticulture Stations including screening trials of seedling raspberries and black currants.

So far comments have been confined to fruit for the fresh fruit market, but the needs of the processor are equally important, and with strawberry, raspberry and black currant trials, samples of the more promising selections are sent to the British Food Manufacturing Industries Research Association,

Leatherhead, for jamming tests, and to the Fruit and Vegetable Preservation Research Association, Chipping Campden, for canning and quick freezing, while critical storage tests of promising new late apples are carried out at either East Malling Research Station or with the co-operation of East Kent Packers Ltd.

As soon as any one trial is complete, a report is immediately issued describing the performance of the more promising selections in comparison with the control varieties, so that information is made available to growers at the earliest possible moment. These published reports, however, do not include the performance of seedlings which have not come up to the required standard, as there would be no purpose in publishing descriptions and records of seedlings which would not be released. From this brief review it will be seen that everything possible is being done to speed up the results of fruit variety trials, while bearing in mind the interests of the grower and breeder.

FROST PROTECTION OF FRUIT CROPS

J. Ingram, *Luddington Experimental Horticulture Station*

One of the main cultural hazards in fruit growing is still the possible loss or reduction in the potential crop that can occur due to frost injury to the flower parts over the blossom period. Careful choice of site can considerably reduce this hazard but frost damage can still occur on even the best sites in some seasons. This is particularly so for the early flowering subjects such as plum, gooseberry, pear and black currant. The later flowering subjects apple, strawberry, raspberry and blackberry are less frequently affected.

The other equally important source of variability in cropping is lack of fertilization due to low day temperatures, as distinct from frost injury, over the blossom period. Frost damage to the developing fruitlets can also occur as with gooseberries and as occurred to apples in 1961 from a late frost on May 26/27.

With some crops such as apples the most profitable seasons in the past have tended to be those when the crop has been light and prices have been high. This is unlikely to be so in the future with adequate competing supplies available from abroad. The increasing need of the processor and the fresh fruit market is for a regular supply of fruit of a standard quality.

Frost protection offers a means of ensuring a more regular supply but can only be considered for the high value crops and those where the frost hazard is greatest.

METHODS OF FROST PROTECTION

There are several approaches to frost protection but only one, continuous sprinkling with water, is at present in use commercially on any scale in this country. Direct heating using oil burners or solid fuel candles and petroleum briquettes are being investigated experimentally by the N.A.A.S. in the south east region. If these are successful and economically acceptable they offer the advantage of providing, in addition to frost protection, a

possible means of increasing orchard temperature to assist fertilization. In the U.S.A. orchard heating is often used in combination with wind machines which are used to pull down the warmer air from above which is useful under strong inversion conditions.

Complete covering of the plantation with material to reduce radiation loss has so far proved uneconomic but new light plastic netting materials are now being tried for this purpose. Other methods being tried include (a) creation of an artificial fog stabilized by coating the water droplets with a chemical film to delay evaporation, (b) covering the plant with a protein foam similar to that used in fire fighting and (c) chemical means.

CONTINUOUS SPRINKLING

The protective effect with this method depends on the transfer of heat from the added water, in part as it cools to the freezing point releasing one calorie per gramme per degree C fall, but mainly by the release of latent heat of freezing of the water as it turns to ice. This is approximately 80 calories per gramme of water frozen equal to about 1,440,000 B.Th.U. per 1,000 gallons.

Costs

Installation of a solid set system for frost sprinkling with pumps and delivery main involves a capital investment of some £250 – £300 per acre as the entire area to be protected has to be covered with equipment. To this must be added the cost of any reservoir required which can vary between £240 and £800 per million gallons or up to £2,000 if it has to be lined.

Water requirement

The essential need is for an adequate supply of water as the required precipitation rate of 0.125 in. per hour calls for a water flow of 47 gallons per minute for each acre covered. There should also be a sufficient reserve of water available to provide for at least three and preferably more successive nights of frost each of eight hours duration. In 1968 at Luddington the total sprinkled time for the season amounted to 50 hours.

Equipment

Good equipment is necessary together with a very high standard of maintenance to avoid breakdowns. Sprinkler type and spacing is important. The spring assembly on each sprinkler should be tensioned to ensure at least one rotation per minute, and the spring should be enclosed to prevent freezing up of the moving parts.

Sprinkler spacing

In order to achieve the low precipitation rate triangular spacing of sprinklers is usually adopted. Results of sprinkler tests carried out at Luddington have shown that an equilateral triangle arrangement (e.g., 80 ft between sprinklers on the line x 70 ft between lines = 7.8 sprinklers per acre) usually ensures a better distribution and coverage of water than an isosceles triangle arrangement (e.g., 80 ft x 80 ft = 6.8 sprinklers per acre).

Water application rate

Present recommendations are that a water application rate of at least 0.125 in. per hour is required to provide a 5°C (9°F) temperature lift (i.e., protecting down to -5°C (23°F)). Some earlier installations based on an application rate of 0.1 in. per hour can only be expected to provide a 2.8°C (5°F) lift.

Operating temperatures

With black currants sprinkling should commence when the falling temperature reaches 0°C (32°F) and should then continue until the temperature again lifts to 0°C (32°F). With apples a water saving of up to 30 per cent can be achieved by delaying the start until the temperature falls to -1.1°C (30°F), but once started at this lower temperature sprinkling should then continue until the temperature lifts to 0°C (32°F).

The temperatures referred to are based on a normal exposed thermometer but the relatively low humidity conditions during the frost sprinkling period in 1969 led to the view that under such conditions a wet bulb thermometer would ensure a better result. The lower temperature reading from the wet bulb thermometer would have brought the sprinklers into operation earlier.

Adjustable contact mercury thermometers wired through a relay should be arranged to ring a bell in the operator's bedroom or if required they can be used to automatically to set the sprinkler system in operation.

The Meteorological Office provide from the London Weather Centre a frost warning scheme for fruit growers, as a guide to when frosts are likely to occur. For a small charge warnings are issued by telephone at any time of the day or night although with a normal radiation frost they can usually be issued by about 5 p.m.

Operation of a sprinkler system

With so much at stake the presence of someone throughout the period of sprinkling is regarded as essential to ensure that the system is operating satisfactorily. Pumps, motors, water pressures and sprinklers need to be checked. A powerful spot torch is useful to check that none of the sprinklers are blocked or not rotating. If sprinkling is interrupted for more than a short time once the bushes or trees are wet they are likely to sustain more damage than they would if no sprinkling had been done at all.

Wider use of the equipment

The wider use of a solid set rotary sprinkler system for the application of spray programmes, nutrients and residual herbicides in addition to the use for frost protection and irrigation could make an installation a more practicable proposition and if successful might eliminate the need for most of the tractor work in the plantation. Preliminary work on these lines is being carried out on black currants at Luddington.

The simplest method of adding materials to a sprinkler system is to feed them, in partly diluted form, into the suction side of the irrigation pump. If this is done care should be taken to avoid putting tar oil through PVC mains as this can lead to breakdown of the pipes.

Injection method

A better method, however, which is essential if the plantation is some distance from the pumphouse or where a submersible pump is installed is to inject the materials into the pressurised overland irrigation main as near to the plantation as possible.

A small injection unit has been developed for this purpose at Luddington but a high volume spraying machine can be used. The partly diluted material is pumped into the irrigation main through a one way valve at a slightly higher pressure than the irrigation line pressure.

Sufficient chemical material for the acreage to be covered is mixed into a small quantity of water in the tank and the rate of injection adjusted to enable it to be fed into the irrigation line over a period of six minutes. With the sprinkler system applying approximately 50 gallons of water per acre per minute, a six minute injection period provides an application rate equivalent to high volume spraying of 300 gallons per acre.

In order to allow for the distance between the injection point and the furthestmost sprinkler the irrigation line is turned off six minutes after the spray material is first observed to have reached the furthestmost sprinkler. This timing can be simplified by mixing a dye in with the chemical material and turning the irrigation off as soon as clear water is seen to emerge from the furthestmost sprinkler.

Satisfactory results have been achieved at Luddington in using the system to apply spray materials, nutrient and residual herbicides to black currants except for the control of the under leaf diseases. Fluorescent tracer tests have shown that the reason for this is that under leaf cover is poor. The new locally systemic fungicides are to be used in 1970 to observe whether successful control of under leaf diseases can be achieved.

EARLY PRODUCTION OF STRAWBERRY RUNNERS

M. R. Pollock, *Ellbridge Experimental Horticulture Station*

Work at Ellbridge and elsewhere has clearly indicated the value of early planting for high strawberry fruit yield in the maiden year, and for Tamar Valley conditions August planting is recommended. Since Ministry certified runners are not available until after September it is the usual practice to lift early runners from mother-plants established from runners certified in the previous season.

There is of course a need to obtain a high yield of early runners and previous work at Rosewarne and at Ellbridge examined the effect on number and quality produced of planting fresh dug mother plants at a range of dates from August to November. No advantages were shown from early planting within this period, but there was a marked decrease in runner yield where mother plants were not planted until the spring.

Recent trials at Ellbridge have compared the effects on early runner production of establishing mother plants from July planted cold stored runners with those from fresh dug runners planted in October. Cold stored

runners are lifted from certified beds in January or February and stored in sealed polythene bags at -1.1°C (30°F) until planting time.

In trials over two seasons yields of plantable runners at lifting dates in August and September have been at least 100 per cent greater from mother plants established from cold stored runners. De-runnering cold stored plants in the autumn after planting had no effect on September yield the following year, but significantly decreased the August yield.

The application of a $\frac{1}{2}$ in. peat mulch in June increased runner yield in the cold stored plots and, to a lesser extent, in the fresh dug plots.

Smaller unreplicated pilot observations suggest advantages in early production from the provision of wind shelter, and also where mother plants are protected with low polythene tunnels from February until June.

Glasshouse and Flower Crops

CONTINUITY PRODUCTION OF GLASSHOUSE LETTUCE

J. B. Rothwell, *Fairfield Experimental Horticulture Station*

In order to supply markets and chain stores with a continuous supply of lettuce it is necessary to plan the cropping programme precisely. When this type of programme is in operation, advantage is gained by spreading the workload and avoiding glut prices for excessive quantities of lettuce.

Information is limited regarding sowing dates and the resultant times of cutting. For this reason it was decided to conduct a trial at Fairfield to determine the dates of maturity of lettuce crops sown at regular intervals. The first sowing was made on 13 August 1968 and this was followed by weekly sowings until 11 February 1969. A wide range of Dutch varieties was tested but only those which were successful are discussed here.

The seed was sown in John Innes seed compost and germinated at 15.6°C (60°F). The seedlings were pricked off into 1½ in. soil blocks consisting of a mixture of 3 parts fine sedge peat and 1 part sterilized loam with the required amount of lime and fertilizers added. The seedlings were stood out block thick in a small propagation house with a temperature of 12.8°C (55°F). Planting at a distance of 8 x 8 in. took place when the leaves of adjacent plants began to touch. A temperature regime of 4.4°C (40°F) night, 10°C (50°F) day and 18.3°C (65°F) by ventilation was used in the growing house. The dates of planting and harvesting relative to each sowing were noted.

Planting stage was reached in a little over 3 weeks on average for the first 9 weekly sowings, but after the middle of October, the period between sowing and planting lengthened to a maximum of nearly 9 weeks from mid-November to mid-December; thereafter this gradually decreased to 4 weeks for sowings made in early February. The interval between planting date and the time the crop reached harvesting stage showed a similar pattern, taking 5 weeks at the beginning of the season, increasing to 16 weeks for crops maturing in February, and declining again to 8 weeks for harvesting early in May. Thus while the overall time from sowing to harvest was 8 weeks for the earliest sowings in this period which were cropped in mid-November, this increased to reach a maximum of 19 weeks for sowings made from mid-October to mid-November which were ready for cutting over the period early February to early April. The total time to cropping subsequently declined to 12 weeks for early February sowings maturing in early May. Sowings made over the 6 week period between early September and mid-October were ready for cutting over an extended period from mid-November to early March, whereas later sowings made over a 2½ month period between mid-November and the end of January all matured during 1 month beginning in early April.

It is apparent that sowing should be done at shorter intervals than 7 days in the period from the end of August to mid-October; during this time sowing every 2 or 3 days would be advantageous. Conversely a sowing every fortnight would be adequate after 12 November.

Varieties were assessed for their performance at specific periods of harvesting. The table shows which varieties were found to be suitable for harvesting within 5 different periods.

Period of Harvesting	Satisfactory Varieties
October and November	Deciso, Amanda, Kwiek, Kordaat, Noran.
December and January	Kordaat, Noran, Kwiek
February	Vitesse, Rapide, Kordaat, Kwiek Amanda, Noran, Magiola, Korrekt
March and early April	Vitesse, Kwiek, Tonika, Kordaat, Noran, Magiola, Miranda, Korrekt
Mid-April to early May	Miranda, Kwiek, Magiola, Knap, Korrekt, Noran, Kordaat, Vitesse, Delta.

Owing to unusually poor winter light conditions the harvesting of these crops was probably delayed. In an average winter the dates of harvesting might be slightly in advance of those given above. Production of good quality lettuce in December, January and early February is difficult using Dutch varieties. It should be possible to improve quality during this period by using the varieties Neptune and Valentine; but for these higher temperatures would be required. The trial in 1969 – 1970 will investigate the use of these varieties in the cutting period December to early February.

SELF BLANCHING CELERY: USE OF EXTENDED DAYLENGTH TO MAINTAIN QUALITY

M. R. Bradley, *Stockbridge House Experimental Horticulture Station*

Several year ago, when celery storage was first investigated at Stockbridge House, the storing of sticks in glasshouses was considered. The sticks, with their roots intact, were loosely packed in an upright position in boxes placed in a glasshouse. While this method was successful in avoiding frost damage the crop was not marketable due to the opening out of the sticks (rosetting). Very late crops of self blanching celery grown in the open have shown the same tendency.

In 1968 when a Christmas crop of glasshouse celery was being considered an experiment was carried out to establish the cause of rosetting. Daylength is obviously one environmental factor that is appreciably different from the daylength at the time celery is normally grown, and so the experiment was aimed at preventing rosetting by artificially extending the daylength.

Plants raised in JIP2 soil blocks were potted up into 6 in. pots and arranged in a glasshouse to give a plant spacing of 10 in. x 10 in. Half of the plants received 8 hours daylength and for the other half, the daylength was extended to 15 hours using 40w tungsten bulbs 3 ft above the crop with each bulb covering an area of approximately 4 ft x 4 ft.

The result of this trial was that for the 4 varieties used (Golden Self Blanching, Lathom Blanching, Avon Pearl and the Stockbridge House selection 90/1) the plants receiving 8 hours daylength rosetted whereas the plants receiving 15 hours daylength remained normal. The photograph (Plate V lower), shows the extent of this rosetting.

In view of this result, the late crop of glasshouse celery grown on the Station had normal daylength of approximately 8 hours extended to 15 hours (the extra light being supplied by 40w tungsten bulbs suspended 8 ft above the crop and spaced at 10 ft x 10 ft); none of the plants in this crop rosetted.

In 1969 eleven varieties were grown in two unheated glasshouses in order to produce a crop for the Christmas market. Both houses were planted in early August. The crop in one house was grown with normal daylength and by mid-November rosetting was apparent. If the crop had not been harvested at that time there is no doubt that it would have been completely unmarketable by Christmas. The crop in the second house had the daylength extended to 15 hours (the extra illumination being provided by the method described above) with the result that none of the plants had rosetted up to mid December at which time the crop was cleared to forestall any frost damage.

These results clearly show that it is possible to maintain late crops of self blanching celery in a marketable condition by artificially extending the daylength. The experiments so far have been based on a daylength of 15 hours although this is not necessarily the best. It is possible that a shorter daylength would have an equally beneficial effect. It has yet to be determined whether this effect is due to the length of light period or to the total amount of light reaching the plants. The economics of the operation must also be established.

TOMATO NUTRITION WITH BASE FEEDING

J. B. Rothwell, *Fairfield Experimental Horticulture Station*

Liquid feeding of tomato crops has become a standard practice on many nurseries. It is claimed that it has many advantages over the application of fertilizers as top dressings at frequent intervals. Liquid feeding is reputed to give a quickly available source of plant food, to save labour and to ensure more accurate control of plant growth due to the variation which can be achieved in soil solution strength. It certainly saves labour when compared with frequent top dressing, but there is some doubt whether it facilitates the control of plant growth. On small nurseries the application of liquid feeds may entail a considerable amount of work. A reduction in the time taken to apply nutrients to the tomato crop has become possible since the introduction of urea formaldehyde fertilizers which give a slow release of nitrogen over a period of several months.

Experiments on sources of nitrogen for late tomato crops have now been in progress for 3 years at Fairfield. During this time it has become apparent that reasonable crops of good quality tomatoes are produced when potash at 1600 lb per acre is given as a base dressing without subsequent

application of this nutrient either as a top dressing or in liquid feed. A combination of this potash base dressing with a urea formaldehyde source of nitrogen is therefore a practical possibility for the later planted tomato crop.

During the 3 experiments we have compared the application of top dressings of 4 sources of nitrogen as fortnightly liquid feeds with base dressings of urea formaldehyde or hoof and horn meal. The sources of nitrogen applied as top dressings were sulphate of ammonia, nitrate of ammonia, nitrate of calcium and urea. In all these treatments nitrogen was applied at the rate of 800 lb per acre and watering was done by hose pipe.

All treatments received a base dressing of 1600 lb per acre of potash in the form of sulphate of potash. The variety Florissant was planted in mid-April.

On the plots which received a base dressing of urea formaldehyde or hoof and horn growth was vigorous and the setting of the flowers almost complete. Picking from all plots began in mid-June, good quality fruit being harvested from the urea formaldehyde plots throughout the season.

Yields were recorded between mid-June and the end of August and are shown below:

Treatment	Yield (lb/plant)
Hoof and horn base	7.2
Sulphate of ammonia top dressing	7.3
Nitrate of ammonia top dressing	6.8
Nitrate of calcium top dressing	6.8
Urea top dressing	7.1
Urea formaldehyde base dressing	7.4

The quality and yield response to the urea formaldehyde base indicates that this method of nutrient supply shows considerable promise for short term tomato crops. To adapt this to longer term crops will entail the use of urea formaldehyde containing a mixture of size grades to provide a prolonged release of nitrogen, or the application of a top dressing 3 months after the base is applied.

The measurement of the conductivity of the soil by the saturated calcium sulphate method gave an indication of the durability of the effect of a urea formaldehyde base dressing. Conductivity measurements were made each month. The values of these in micromhos were 2,450 on 21 April, 2,700 on 12 May, 2,500 on 20 June and 2,200 on 22 July. Thus the soil solution strength was conducive to the production of good quality fruit in April, May and June, but was too low for this purpose in July. During 1970 we are extending this work to ascertain the effects of various methods of water application when a urea formaldehyde - sulphate of potash base dressing is used without liquid feed being applied. The 3 irrigation systems which will apply nutrient-free water are the overhead type, the low level diffuser type and the trickle irrigation system. These 3 systems will be compared with a trickle irrigation system applying water containing liquid feed.

FORCING CHICORY

J. A. Hayes, *Lee Valley Experimental Horticulture Station*

The forced and blanched heads of chicory (*Cichorium intybus*) are, at present, almost entirely imported from Belgium. The value of these imports is about £250,000 per annum. There is no apparent reason why chicory should not be produced in Britain and a preliminary investigation conducted in 1969-70 at Lee Valley is examining the possibilities.

Seed of sixteen varieties of continental origin was obtained from Denmark France and Holland, the varieties having been selected to provide continuity of forcing. Sowing was carried out on 11 June in rows 18 in. apart and chlorpropham at 2 pints of a 40 per cent commercial material to the acre was applied as a pre-emergence herbicide. The crop was singled to 9 in. apart in the row on 17 July. Harvesting of the roots was carried out during the last week of October and, despite the dry season, quality and size of the roots was good. The tops were trimmed to $\frac{3}{4}$ -in. above the crown before placing the roots in chitting trays under cover to dry for fourteen days. The roots were then placed in clamps covered with straw in an open shed until required for forcing.

In 1969-70 forcing was carried out in a controlled temperature store but in future years an insulated film plastic tunnel will be used. The forcing beds were constructed with retaining boards 18 in. high and on 4 November five of the earliest varieties were bedded in these with J.I.P.I. washed in around the roots and a 6-in. layer of sand on top. A temperature of 10°C (50°F) was given for 10 days, followed by 15.6°C (60°F) until harvesting, which began on 2 December, 28 days from the start of forcing. Quality was excellent and the heads of chicory were marketed in cardboard containers, lined with waxed paper, holding approximately five pounds.

A succession of crops was forced until March and it is reasonable to expect six crops from each forcing house during the period October to March. In addition to testing the sixteen varieties, various media for covering the roots were examined.

The production of forced chicory is not without problems, but in the future there would appear to be possibilities for the development of this crop in Britain.

SALAD CROPS IN WALK-IN POLYTHENE TUNNELS

R. W. K. Holland, *Lee Valley Experimental Horticulture Station*

During 1969 a number of cropping rotations were tested in unheated 14 ft wide polythene tunnels. They included the salad crops lettuce, tomato, sweet pepper and celery.

The season was unusual in that temperatures were lower than normal until mid-May: later there was more sunshine than in most years and temperatures were high. Spring crops were therefore rather late maturing and some crops may have suffered due to the high summer temperatures.

LETTUCE

One tunnel ($\frac{1}{8}$ acre) was planted in early December with lettuce for spring maturity. Dutch glasshouse varieties were used. They were harvested at the end of April when a gross return of approximately £70 was obtained.

A later spring crop which included Dutch glasshouse and outdoor types was planted in mid-March. In general the outdoor varieties were slower to mature and some were not ready when harvested in early May. The overall returns were equivalent to approximately £38 per $\frac{1}{8}$ acre tunnel.

One tunnel was assigned to a rotation comprising crisp lettuce. In most summers it should be possible to obtain a cleaner, more tender lettuce with protection than in the open, in which case improved returns should justify the use of tunnels. The variety Avoncrisp was used throughout.

The first crop was planted mid-March and harvested late May. It was followed by another crop which was harvested in mid-July and a third which was cut in late August. A fourth crop was then planted but did not reach maturity by December when the tunnel had to be cleared. The quality of the first crop was quite good and the gross returns for the $\frac{1}{8}$ acre were £30. However, the next two crops clearly suffered as a consequence of the unusually hot weather. Growth was very soft and plants were prone to *Botrytis* which caused much wastage so that returns were very low. If more ventilation had been provided, growth would have been much better and it is planned in future lettuce continuity trials to perforate the polythene during hot weather to allow lateral as well as longitudinal movement of air. Other varieties will also be tried to see whether they are more suitable than Avoncrisp for this type of production.

Experience in 1969 has shown that if butterhead lettuce are to be grown as an autumn crop on this site they must be planted by mid-September or given heat assistance. In a tunnel planted in late September about 60 per cent were marketable but in tunnels planted in early October, no lettuce were mature enough to cut before they were damaged by unusually severe frosts in mid-November.

TOMATO

A tomato crop raised from a late March sowing was planted out in a polythene tunnel in early May at a density of 14,000 plants per acre. Initially the tunnel was kept closed most of the time to keep temperatures as high as possible. However, it became apparent that high humidity was encouraging the development of ghost spot (*Botrytis*) on the fruit; thereafter some ventilation was given all the time and the spread of ghost spot was kept at a very low level.

Once the plants had grown tall there was a great deal of obstruction to air movement and as a consequence temperatures frequently rose well above 32°C (90°F). This, coupled with low fertility of the site, led to a high proportion of the fruit being in Classes 2 and 3.

Of the four varieties grown, Moneycross had a lower yield than Eurocross B, Eurocross BB, and Selsey Cross and gross returns for this variety were calculated to be equivalent to approximately £1,500 per acre compared with about £2,000 per acre for the other three varieties.

The experience gained in 1969 should enable considerable improvement

in fruit quality to be achieved in future crops of tomatoes in polythene tunnels. This crop, like lettuce, would probably benefit from perforation of the polythene to increase ventilation during the hottest summer weather.

SWEET PEPPER

One tunnel of $\frac{1}{48}$ acre was planted with this crop in early May. Nine varieties were used, one plot being planted with each. Harvesting started 27 June and continued until the tunnel was cleared on 2 October. By this time the total yield of marketable fruit was 8 cwt and one variety, the F1 hybrid Canape, had yielded the equivalent of nearly 12 cwt per tunnel with a gross return of £135.

The labour requirement of the sweet pepper crop was low. The only training carried out was staking the plant and tying it to the stake twice during the growing period. Furthermore, picking was carried out only once a week so that labour required for this operation was less than with tomatoes. The low labour input coupled with the high gross return makes this crop look very promising.

CELERY

Two crops of celery were grown in polythene tunnels. The first was aimed at an early market prior to the appearance of celery from the open and the second crop was to be harvested in December when the amount of celery available had declined. The variety Lathom Blanching was used for both crops.

The early crop included a comparison of three sowings made at the end of January, mid-February and early March. Sowing was done in a heated glass-house and the plants were planted in the tunnels in mid-April and early May.

Gross returns from the first two sowings which were harvested in late June were similar and equivalent to about £110 per $\frac{1}{48}$ acre tunnel. However, plants from the last sowing were 2 – 3 weeks later maturing. Market prices had dropped by this time due to exceptionally warm weather and the returns were only £15 per tunnel. It is therefore inadvisable to delay sowing after mid-February.

For the autumn crop half of the area was planted with seedlings direct from the seedbox and the other half was planted at a later date with seedlings pricked off into containers. Harvesting was carried out in early December by which time the sticks had been damaged by frost so that trimming was necessary and this reduced the size and value of the sticks. Gross returns for direct planting (£26 per $\frac{1}{48}$ acre tunnel) were slightly higher than for containerising prior to planting and as the cost of the containers was eliminated by the former treatment it appeared to be a promising system.

In order to protect the second crop from frost it will in future years be covered with straw before the first hard frost. In this way the size of stick marketable and gross returns should be increased.

SUPPLEMENTARY ILLUMINATION OF ALL YEAR ROUND CHRYSANTHEMUMS

I CUT FLOWERS

F. G. Lloyd, *Lee Valley Experimental Horticulture Station*

Owing to the increasing cost of rooted cuttings and of other aspects of production, serious consideration must be given to any method of reducing the production schedule for winter planted chrysanthemums and of improving the quality and uniformity of the crop.

With these aspects in mind an experiment was commenced in January 1969 to study the effect of the illumination of rooted cuttings prior to planting. The method used at this Station could be of interest to suppliers of chrysanthemum cuttings and it also could have application to growers of cut flowers.

The illumination treatments were as follows:

- | | | |
|--|---|---|
| <ul style="list-style-type: none"> a) High pressure mercury (400 watt lamps — 16 hours illumination each day from 1.0 a.m. — 5.0 p.m. for 15 days b) As for (a) but illumination for 10 days c) Incandescent lamps 60 watt — night break for four hours per night for 15 days | } | <p>Prior to planting
in flowering house</p> |
| <ul style="list-style-type: none"> d) Control — planted direct into flowering house, illuminated by incandescent lamps — 60 watt, four hours per night, 10.0 p.m. — 2.0 a.m. | | |

The rooted cuttings, illuminated before planting, were inserted in a 1½ in. deep layer of peat compost on a bench in a glasshouse at a temperature of 14.4°C (58°F) night, 18.3°C (65°F) day with ventilation at 21.7°C (71°F). The cuttings were spaced 1½ in. x 1½ in. but further work has shown that 2 in. x 2 in. is preferable.

Illumination of the cuttings of all treatments was continued in the flowering house by incandescent lamps for four hours per night from 10.0 p.m. — 2.0 a.m., to provide night breaks until the plants had made sufficient vegetative growth to ensure that stem length would be adequate when the plants were harvested.

The schedule is shown below:

28 January	—	illumination treatments commenced.
7 February	—	plants receiving 10 days illumination from mercury vapour lamps were planted.
12 February	—	plants receiving 15 days illumination from mercury vapour lamps and incandescent lamps on the glasshouse bench, were planted.
22 February	—	night break illumination ceased on all plants in flowering house.

By 22 February when night break illumination ceased, even the smallest plants of the most backward treatment – (c) had made adequate vegetative growth. This period of $3\frac{1}{2}$ weeks of night breaks is normal for A.Y.R. chrysanthemums planted in winter at Lee Valley.

The crop was managed in the normal way as soon as all planting was completed. Flowering commenced on 30 April and although the results obtained were not clear cut, were of sufficient interest to continue the work on a more detailed scale in 1970.

Of the three spray varieties used the 15 day illumination with mercury vapour lamps gave earlier flowering on Delmarvel and Iceberg but it had no effect on Portrait.

Illumination by mercury vapour lamps produced larger plants with larger root systems than those receiving illumination from incandescent lamps before planting. To avoid root damage these larger plants needed more careful handling when set out in the flowering house, but the use of small individual containers for the plants illuminated on the bench would overcome this. The 15 days of illumination from mercury vapour lamps produced slightly higher numbers of top grade blooms as judged by those with 8–9 open flowers per spray but when the 6–7 and 8–9 grades were compared there was very little difference between treatments within each variety.

Illumination of rooted cuttings prior to planting reduces the time that the plants are in the growing house and according to illumination treatment this saving can be 15 – 21 days. If the plants illuminated by mercury vapour lamps for 15 days on the bench are placed in individual containers on receipt, a second establishment period when set out in the growing house would be avoided. This could reduce or obviate the need for night breaks after planting and lead to a further reduction in time in the growing house. It is hoped that this aspect will be included in the experiment starting in December 1970. The saving in time that the crop occupies the growing house would increase the throughput from it and give a higher monetary return per year.

II POT PLANTS

D. R. Wade, *Lee Valley Experimental Horticulture Station*

Work undertaken at the Unit of Flower Crop Physiology, Reading, by Dr. Hughes and Dr. Cockshull shows that flower initiation in the chrysanthemum occurs during the first few days of short day conditions. A light level of 30 cal per cm² per day is desirable for uniform initiation. Even in the south of England this level is rarely achieved during the months of November to January and quality of the plants is consequently poorer than at other periods of the year.

With the objective of improving winter quality the Lee Valley Station has investigated the commercial application of illuminating pot chrysanthemums in a growing room, where a light level of 15,000 lux for 8 hours per day is equivalent to 32 cal per cm². The light is provided by banks of 13 white fluorescent tubes.

Results of trials undertaken during November 1968 confirmed that benefit

was obtained by illumination. Four varieties were potted on November 6 in J.I.P.2 compost and subjected to three long days (4 hr. night break lighting) prior to moving into the growing room on November 13. In the growing room treatment for 7 and 14 days at 2 light intensities was investigated. The highest light level given for 7 or 14 days was of most interest. Flowering was more uniform and considerably earlier than with unilluminated plants. Overall quality was distinctly improved and there were indications that continuing treatment for 14 days increased flower size. Cuttings potted singly in 3½ in. pots showed a greater benefit from illumination than 5 cuttings in a 5½ in. half pot. It was thought that the greater mutual shading between cuttings was the cause of this effect. Recently a comparison between 4 and 5 cuttings per pot showed that illuminating 4 cuttings produced a pot plant of good quality with only one flower less than with 5 cuttings per pot. The possibility of reducing the number of cuttings and yet improving the overall quality is obviously of interest when the economics of illumination are considered.

Experiments are in progress to determine the most suitable programme for illumination and will include an examination to ascertain whether plants should be illuminated directly after potting or whether there is any benefit in giving a period of natural or long days before illumination. In addition the investigation will include an examination of the effect of giving a short period of long day illumination under lights at 8,000 lux prior to switching to short day illumination. Also we are interested in the response of varieties to illumination and particularly their reaction to the transition from the relatively high intensity illumination to the poor and variable natural winter light conditions.

With economics in mind, the fact that only 108 5½ in. pots can be accommodated under a single bank of 8 ft. fluorescent tubes means that illumination of pot chrysanthemums on the glasshouse bench using light resources such as the MBFR/U (or HPLR) mercury discharge lamp and the HLRG type mercury fluorescent tungsten lamp may well be more suitable.

TULIP FIRE: METHODS OF CONTROL

J. B. Briggs, *Kirton Experimental Horticulture Station*

D. Price, *Glasshouse Crops Research Institute*

Tulip fire caused by *Botrytis tulipae* is one of the most widespread and troublesome diseases of the tulip and work on various aspects of its control has been carried out at Kirton for over 10 years.

Until 1968, work had been concentrated on finding methods of preventing the spread of foliar infection by leaf sprays. Throughout the series of experiments the unsprayed control plots gave a consistently lower bulb yield than the sprayed plots and demonstrated convincingly the benefit to bulb yield of regular applications of an efficient fungicide. Early spraying from 100 per cent bulb emergence is important: thereafter, spraying at 3 week intervals

is thought to be sufficient and more frequent applications are unnecessary except in periods of very wet weather. One final spray after flowering is all that will be required in a dry season. Materials which give an effective control of fire on the leaf include mancozeb, zineb, mancozeb/zineb and dichlofluanid.

Bulb infection will still occur, however, irrespective of the efficiency of fire control on the foliage, making it necessary to rogue out primary infectors as they appear. Early roguing is particularly important because it reduces secondary infection of the plants round the primary infectors and increases the probability of effective control by spraying. However, a reappraisal of methods of controlling tulip fire occurred following the discovery at the Glasshouse Crops Research Institute that bulbs infected with *B. tulipae* at planting are more likely to develop into primary infectors if the infection is near the neck of the bulb; if it is not, although the shoot may grow and appear healthy, the infection may continue to develop underground and be transferred to the daughter bulbs. Complete control will therefore only be possible if *B. tulipae*, which occurs as sclerotia on outer bulb scales, old flower stalks and fleshy scales, as well as mycelium within fleshy scale lesions, can be killed in the bulb, thus preventing primary infectors and underground transfer.

For the past 2 years work on this latter approach of bulb dipping prior to planting has been carried out at Kirton and the GCRI. During this time, a method of infecting tulip bulbs with *B. tulipae* has been developed so that a uniform infection can be guaranteed before dipping the bulbs in fungicide, thus enabling its efficiency in controlling fire to be assessed accurately and compared on bulbs planted in the field.

Bulbs were inoculated with *B. tulipae* sclerotia at Kirton on 13 September 1968 and were then stored at a humidity of between 60–70 per cent in a controlled temperature cabinet at 15.6°C (60°F) to encourage the germination of the sclerotia and formation of small fleshy scale lesions.

On 8 October batches of the inoculated bulbs were dipped for 30 minutes in different fungicides thought to be effective against *B. tulipae* on the bulb and dried before planting in ridges in the field on 11 October. At intervals throughout the growing season, 50 bulbs from each treatment were lifted and examined for the progress of the disease.

Numbers of bulbs with enlarging B. tulipae lesions out of 50 bulbs lifted

Treatment	Rate a.i/ 25 gal water	Lifting date				TOTAL
		28 Feb.	11 April	8 May	26 June*	
Quintozene	2 oz	33	41	44	16	134
Methoxyethyl mercury chloride	0.3 oz	38	41	46	18	143
Dicloran	4 oz	44	50	45	15	154
Thiabendazole	4 oz	30	41	30	18	119
Drazoxolon	10 oz	44	42	47	24	157
Water dip only		37	45	43	18	143
Undipped control		45	37	39	26	147

*Mother bulb tissue disintegrated on many samples.

These results show that these fungicides were of little use in controlling the development of mycelial lesions, although experiments at the GCRI have shown the effectiveness of methoxyethyl mercury chloride and thiabendazole in killing sclerotia, but the effectiveness of the former material must be weighed against hazards of using mercurial formulations.

Dipping bulbs in one of these fungicides would reduce but not eliminate fire in a stock and it is unlikely that such treatment would produce a sufficiently clean stock to make roguing of primary infectors unnecessary. However, since the start of this work, other systemic fungicides have become available and one which has shown promise in controlling sclerotia and lesion growth is being included in the next in this series of dipping experiments.

NARCISSUS STORAGE TREATMENTS FOR EARLY OUTDOOR FLOWERING

A. A. Tompsett, *Rosewarne Experimental Horticulture Station*

Cool storage of narcissus bulbs before planting is now common practice amongst early flower growers in south-west England. Experiments at Rosewarne have shown that cooling for 6 weeks at 9°C (48°F) before planting in September gives the maximum advancement of flowering date. Shorter durations have less effect but to maximise the throughput of a store, two successive batches of bulbs may be treated for 4 weeks giving a 10 to 14 day loss of earliness in the ensuing flower crops. For successive batches, planting should be between mid-August and mid-October.

Mean flowering dates of N. Magnificence planted on 28 September were advanced from 25 February to 20 January in 1968 by cooling for 6 weeks at 9°C (48°F) and N. Golden Harvest from 7 March to 5 February. Whilst this greatly increases the value of the flower crop, cooling results in a considerable reduction in bulb weight increase. With Golden Harvest down for one year a bulb weight gain of 69 per cent in the uncooled crop was reduced to 34 per cent by cooling whilst for Magnificence the figures were 64 per cent and 4 per cent respectively. Moreover it has been noted that bulb weight increase is least with the earliest flowering treatment. One possible explanation is that exposure of the foliage to adverse weather early in the year may result in leaf damage and early senescence. However, more recently a connection has been observed between cooling and the degree of leaf scorch disease, (*Stagonospora Curtisii*) and this could be a further reason for the undesirably early senescence of many cooled crops.

Formerly this cooling technique was carried out on narcissus bulbs not receiving hot water treatment for the control of eelworm. Hot water treatment invariably resulted in damaged flowers making the crop unmarketable. Experiments at Rosewarne have confirmed that a period of warm storage before hot water treatment eliminates this problem, as well as producing a beneficial effect in advancing flowering. Current recommendations are therefore to store bulbs for 5 days at 35°C (95°F) or 4 days at 34°C (93°F) immediately before hot water treatment. If lifting and treatment are carried

out early, the bulbs must be held at 17.2°C (63°F) until the flower parts are fully formed (Pc stage) when they are ready for cool storage. This is normally mid-July in south-west England.

Apart from the importance of maintaining eelworm control, additional benefits are observed following hot water treatment of bulbs prior to pre-cooling. The warming process stimulates a more vigorous growth and advances flowering while appearing to delay the onset of senescence. The aim of current work is to test a range of cultivars which when treated in this way will give a succession of flowers and an acceptable bulb yield. Many new and expensive cultivars pose the problem of deciding whether to cool the bulbs to obtain early flowering or leave them untreated for maximum bulb increase. Treatments which optimise the two aspects may result in achieving the best of both worlds.

DUTCH IRIS AS AN OUTDOOR CUT FLOWER

A. A. Tompsett, *Rosewarne Experimental Horticulture Station*

Outdoor iris cultivation has been practised for many years in Cornwall. The main cultural problem is the high incidence of leaf diseases in the mild westerly areas and their effect on flower quality and production and yield of bulbs. The diseases, Leaf Spot (*Didymellina*) and Ink Spot (*Bipolaris*) are less serious in the first year from planting than in the second and subsequent seasons, when the crop can be severely damaged causing both flower and bulb yield to dwindle.

Commercial growers in Cornwall have adopted a system of annual re-planting to overcome these problems, but this is a costly operation and the alternative possibility of long term cropping is currently being studied at Rosewarne.

In 1964 satisfactory control of both leaf spot and ink spot was obtained by fortnightly sprays of tank-mix zineb with white oil. Further work has shown mancozeb also to be effective at least against ink spot, the predominant disease at Rosewarne. Work on leaf spot is being carried out on other sites in Cornwall by the N.A.A.S. Plant Pathologist, Starcross, and workers at the Glasshouse Crops Research Institute. In current experiments at Rosewarne spraying continues from emergence in October until the following May. A lessening of this programme would make spraying more attractive commercially, but in a wet climate this presents difficulties.

Coupled with the improved disease control by spraying we have obtained a very interesting response to the burning of straw over the ground during the dormant season (July – August). Ten tons of straw per acre, although only raising the soil temperature at bulb depth very slightly, and for only a short period of time, does result in a marked advance in growth and flowering. The combined effect of burning straw and mancozeb spraying in the growing season has, on an experimental scale, resulted in a flower crop worth eight times as much as the untreated crop. Burning itself appears to give no protection against disease attack, but in conjunction with spraying produces a healthy crop which in this case commenced flowering in the third week of

April 1969, several weeks ahead of the untreated crop. With improved herbicides and eelworm free stocks it appears that with these treatments, iris beds could be kept highly economic for several years. With the greatly increased vigour obtained, overcrowding could become a problem however, and the optimum life of a bed has yet to be worked out.

Flowering date greatly affects market price and most interest is in the early flowering cultivars Wedgwood, and its sports, Ideal and Dominator. A wide range of other cultivars has been tested for outdoor flowering but though many are most attractive, the majority are late flowering. One possible use for these cultivars may be for the production of out of season cut flowers by means of retarding treatments.

A collection of some 50 cultivars including the de Graaff 'Beauty' range is therefore being tested for their response to retarding. Bulbs are stored for some ten months at 30 °C (86 °F) followed by six weeks at 17 °C (63 °F). The bulbs are planted in August-September for November-December flowering under structures or slightly heated mobiles. Limited success has been achieved with a number of cultivars not previously recommended for this technique.

EVALUATION OF ROSE ROOTSTOCKS

Miss S. Copestake, *Luddington Experimental Horticulture Station*

The systematic evaluation of rose rootstocks used in the United Kingdom has long been in demand by the trade. The estimated 70 million stocks imported each year from Holland, Germany and Denmark are of a limited number of types consisting mainly of *Rosa canina* (English Briar) and its selections (Edal caninas): *Rosa multiflora*, *Rosa rubiginosa* and *Rosa dumetorum* Laxa are also used. Thirteen of the most popular and easily obtainable stocks have been included in trials which commenced in 1967 on three sites and four soils. One of the trials is being run in conjunction with Merrist Wood Agricultural College, Surrey. The two other sites are at Shardlow Hall, Derbyshire and Luddington E.H.S., Warwickshire. Information on stock scion interaction has been obtained using Peace and Ena Harkness representing differing vigour groups. The questions which needed to be answered about these stocks included the ease of nursery establishment related to size and quality of stock obtained, hardiness, handling characters concerned with budding, 'heading back' and harvesting operations and relative characters of flower number, sucker production and disease resistance. The rootstock and budded scion variety interact and the bush type produced is a combination of soil type, site and management so that a correct choice of stock is necessary. For the purposes of this interim report, the thirteen rootstocks have been provisionally classified into three categories of vigour conferred by the stocks on the maiden bush. Grade I numbers where given, refer to bushes with three or more strong shoots as a percentage of stocks planted.

At the head of the vigorous group are two selections of the variable *Rosa multiflora*, thorny and thornless types. This stock appears to be especially sensitive to *Verticillium* wilt resulting in poor establishment, bud take and

consequent Grade I number. The large stocks are less easy to handle due to a multi-branching head and surface roots and 5-8mm graded stocks by budding time can be too large for easy budding. Precocious maiden growth exposes susceptible growth to 'blowing out' in early summer. Bushes are very vigorous with a low degree of suckering and a large number of flowers.

Rosa canina Inermis is vigorous, virtually thornless and is easy to handle. Habit of bush produced is upright but good with a satisfactory flower number. Sucker production at 2 per bush is rather more than other *R. canina* selections. A high number of Grade I bushes, 72 per cent, reflects the good performance of this stock.

Rosa dumetorum Laxa although vigorous is sensitive to pH and performs best at 6.5 or over. Good points are a low production of suckers, freedom from mildew, good handling characters and an upright habit. Faults include a susceptibility to rust disease in some areas of the country but this is unlikely to attack garden roses. The flower number is lower than the vigour might suggest.

Rosa canina Pfander is vigorous with few thorns, less than one sucker per bush, an average production of flowers but easy to handle and bud. The stock is sensitive to mildew.

Rosa canina Heinsohn's Rekord has an initial straggling growth habit and is sensitive to mildew but produces a vigorous bush. The stock is easy to bud and handle. Flower numbers and suckering are average and Grade I numbers are good at 69 per cent.

Rosa canina Superbe handles well but is similar to Pfander in sensitivity to mildew. Suckers are average at 1 per bush and also flower numbers are average. Grade I bushes are high at 68 per cent.

Rosa canina Schmid's Ideal is vigorous but with average thorniness and sucker number at 1 per bush. Budding is fairly easy on the bushy stocks which are slightly sensitive to mildew. Flower numbers are satisfactory and bushes grade well at 71 per cent.

Rosa rubiginosa lies at the lower end of the vigorous group and has faults such as many thorns, a large sucker production at over 3 per bush and the stock handling is difficult. Flower numbers are low but Grade I average at 65 per cent.

The popular *Rosa canina* Wild or English mixed briar comes down into the average vigour grouping and its performance has been disappointing. Variable thorniness makes handling difficult and $2\frac{1}{2}$ suckers per bush is high. A low flower number and 57 per cent Grade I together with a sensitivity to mildew makes this less desirable than its selections.

Rosa canina Brog's has average vigour, few thorns, being an upright bushy stock with some mildew sensitivity. Characters listed are average with 64 per cent Grade I bushes produced.

Rosa canina Pollmers despite a vigorous bushy stock habit seems to produce only average vigour bushes. Handling is easy and mildew is seldom a problem. Sucker numbers are average at one per bush together with average flower numbers and only 55 per cent Grade I bushes.

Rosa canina Succes is unpleasant to handle due to a stiff thorny habit, suckering is high at $3\frac{1}{2}$ per bush and low flower numbers and 51 per cent Grade I put this stock at the bottom of the list.

These brief descriptions of characters so far studied may serve to help rose growers in the future in choosing the best stocks suited to their particular systems of production and ultimately, therefore, giving customer satisfaction.

Vegetables

ECONOMIC EVALUATION OF HERBICIDE TREATMENTS ON BRUSSELS SPROUTS

J. D. Whitwell, *Kirton Experimental Horticulture Station*

In this experiment the sprout variety Champion was direct drilled on 1 April and treated with pre-and post-emergence herbicides as shown in the table below. The pre-emergence sprays were applied on 4 April and the post-emergence sprays on 14 May except the desmetryne which was applied on 4 June. The object of these treatments was to obtain weed control over as long a period as possible.

The plot rows were drilled 21 in. apart and the seeds spaced 2 in. apart in the row. Stand assessments were made and on 14 May plants were thinned to 21 in. in the row. The plants on all plots were stopped on 4 September. Single destructive harvesting was carried out on 13 November and the buttons removed from the stems with a Dokex stripper.

A summary of the effects of the treatments on hand weeding time and total marketable yield are given in the table. Distribution in size grades and sprout quality were fairly constant between treatments.

Handweeding times and marketable yield per acre

Herbicide treatment		Hours handweeding per acre	Marketable yield, tons/ac
Pre-emergence	Post-emergence		
1. }	simazine	9	5.7
2. } nitrofen +	desmetryne	11	6.7
3. } chlorpropham	propachlor	33	7.0
4. }	handweeded	74	8.0
5. }	simazine	6	7.0
6. } propachlor	desmetryne	12	8.0
7. }	propachlor	13	7.9
8. }	handweeded	50	7.8
9. handweeded	handweeded	105	7.6
Mean		35	7.3
S.E. (for diffs)			± 0.655 (16)

Treatment 1 gave a significantly lower yield than the others, and treatments 4 and 6 were higher than treatments 1, 2, 3, and 5. The other treatments showed no significant differences in yield.

Although hand weeding times were not analysed it is apparent that the control plots which were handweeded throughout took longer to weed than plots receiving herbicide treatment; treatments 1, 2, 5, 6 and 7 took less time than the other treatments.

The general system of growing this direct-drilled Brussels sprout crop is common to all treatments, and only 3 items of input differ, i.e., the cost of the herbicides, the number of hours spent in handweeding the crop and the cost of the 20 lb nets for marketing the crop. The output differs in terms of total marketable yield produced only, because all treatments were harvested on the same day, and a common price was obtained for all sprouts sold. The effect of the herbicide treatments on the profitability of the crop enterprise can therefore be measured by comparing the different gross margins which result from the variable inputs and outputs due to treatments.

The gross margins calculated on the results of this experiment taking these variable factors into account varied between £258 and £373 per acre, a difference of £115, which is a sufficient sum to justify careful selection of herbicide treatment.

Treatment 1 gave a lower gross margin than the others mainly due to a low yield. This was probably due to the simazine application post-emergence, because the same pre-emergence treatment followed by handweeding gave satisfactory results. There may have been an interaction here between the pre-emergence and post-emergence treatments, because as the table shows simazine after propachlor did not suppress yield as much as simazine after nitrofen + chlorpropham.

Generally speaking propachlor used pre-emergence produced better results than the nitrofen chlorpropham mixture applied pre-emergence. Surprisingly the handweeded control produced a better gross margin figure than any of the nitrofen chlorpropham pre-emergence treatments followed by post-emergence herbicides and was also better than propachlor followed by simazine.

The two treatments which produced the best gross output were propachlor pre-emergence followed either by propachlor or desmetryne post-emergence. Almost as good were a pre-emergence application of either nitrofen + chlorpropham or propachlor followed by handweeding. The conclusion obtained by this method of assessing the results is slightly different from that obtained by looking at the experimental data on weed cover, plant stand, weeding times per plot and yield etc, but the general trends are the same.

BRUSSELS SPROUTS SPACING: RECTANGULAR & SQUARE ARRANGEMENTS

M. B. Wood, *Stockbridge House Experimental Horticulture Station*

Experiments on the spacing of Brussels sprouts for single harvest production carried out at Stockbridge House and other stations during 1963-66 showed that the maximum yields in the grade preferred for quick freezing ($\frac{3}{4}$ in. to $1\frac{1}{8}$ in.) came from plants grown at a spacing of 18 in. square. Maximum yields in the larger grades (up to $1\frac{1}{2}$ in.), more suitable for the fresh market, came from plants at a square spacing of 21 in.

Many growers prefer to use a common row width, e.g., 28 in. for all their row crops. For this reason trials were carried out on rectangular arrange-

ments for Brussels sprouts at Stockbridge House in 1968 and 1969. In each case the plants were raised in seedbeds and planted out. The variety Topscore was used in 1968 and Peer Gynt in 1969. Square and rectangular spacings were compared and equivalent pairs of plant populations were achieved using spacings of 18 in. x 18 in. and 28 in. x 12 in., 21 in. x 21 in. and 28 in. x 16 in. and 24 in. x 24 in. and 28 in. x 20½ in. A spacing of 27 in. square was also used to establish the effect of wider spacing.

In the 1968 trial three harvests were taken on 18 September, 15 October and 5 November. At each harvest the closer spacings led to higher total yields with a higher proportion of sprouts in the ½ in. to 1 in. diameter grade. On average the rectangular arrangement produced no adverse effect on yield compared with square spacing.

Two harvest dates were used in the 1969 trial, 29 September and 30 October, when an almost identical cropping pattern to that produced at the first two harvests in 1968 occurred.

In both years the proportion of waste sprouts increased with successive harvests and with each decrease in plant density (Plate VI upper). Close spacing delayed maturity however, and as common harvest dates were used for all spacings, the sprouts on plants at the wider spacings were overmature at the later harvests.

At the first harvest in the 1968 trial the plants at 24 in. square and 28 in. x 20½ in. gave similar yields to the four closer spacings. Because of the increased costs associated with the higher density crops spacings of 24 in. square or 28 in. x 20½ in. may be justified for early cropping although fewer sprouts in the ½ in. to 1 in. grade can be expected.

Plants grown at 18 in. or 21 in. square have straighter stems than plants grown at rectangular spacings of equivalent density. This was particularly noticeable in the 1968 trial and is illustrated in PLATE VI (lower). Bent and leaning stalks are more difficult to harvest mechanically than straight ones and the sprouts themselves are more likely to be damaged during stripping through the machines currently available. Where in-row treatments are to be applied to a crop e.g., insecticide granule application at drilling or planting time, a saving in materials will result from using a rectangular plant arrangement rather than the equivalent square one. This is due to the shorter total row length required per acre for the desired plant population.

These trials have shown that for varieties of a compact habit similar to Peer Gynt rectangular spacings can be used without detriment. Spacings of 28 in. x 12 in. for plants which are to be harvested for the quick-freeze market and 28 in. x 16 in. for the fresh market are acceptable alternatives to the equivalent square spacings. However, where the production of straight rows and stems for mechanical harvesting and stripping are required, square spacings are preferable.

SPRING CABBAGE HERBICIDES

J. R. Chrimes, *Rosewarne Experimental Horticulture Station*

Spring cabbage, cut unhearted as 'greens', is one of the three major vegetable crops grown in Cornwall occupying about 2,500 acres of land each winter. Traditionally the crop is planted out from a seedbed.

Because of the economies possible with direct-drilling a small but increasing percentage of the crop is being grown in this way on club root free land. As the effectiveness of this technique is dependent upon the use of selective herbicides, various materials are being compared for both direct-drilled and transplanted crops at Rosewarne.

For herbicide work on direct-drilled cabbage in 1969 graded seed was precision drilled on 21 and 30 July. On each date three varieties of spring cabbage were used (Winter Green, Early Giant and Collards B.G. 283), all of which have consistently given high yields of greens at Rosewarne. On the day following drilling six different pre-emergence residual herbicides were each applied to two-thirds of an acre.

On both dates of application 3.9 lb a.i. per acre propachlor gave the best control of weeds – namely 0.8 weeds per square foot 25 days after application to a damp soil and 5.0 weeds per square foot 25 days after application to a dry soil. Chickweed and mayweed were the two important weeds not affected; knotgrass is also resistant but little was present in this crop.

Aziprotryne at 1.75 lb a.i. per acre was a little less effective than propachlor (3.7 and 8.3 weeds per square foot after 25 days under damp and dry conditions respectively). This material proved ineffective against chickweed, speedwell, charlock and sowthistle.

Nitrofen at 3.5 lb a.i. per acre plus 0.25 lb a.i. per acre chlorpropham gave a result of 9.3 weeds per square foot 25 days after application to a dry soil but 21.0 when applied to a damp soil.

Sulphallate at 1.8 lb a.i. per acre plus 0.5 lb a.i. per acre chlorpropham was also disappointing and produced a result under both dry and damp conditions similar to that achieved with nitrofen under damp conditions. Both materials were ineffective against shepherd's purse and groundsel, and nitrofen failed to control sowthistle.

The two remaining herbicides which are in the development stage controlled weeds less well than either propachlor or aziprotryne. One of the two caused chlorosis of the cabbage cotyledons, reduced the plant stand and both materials reduced the eventual yield.

The plots sprayed with the four herbicides mentioned by name were hoed twenty-five days after the application of the herbicides and again on 8 September before simazine was applied to one half of all the treatments at 6 oz. a.i. per acre (12 oz per acre commercial product). Weed control was good and sample plots from all treatments were harvested on 2 December. There was no difference in yield between any pre-emergence treatment whether simazine was used post-emergence or not (all yields were around 11 tons per acre).

Work was also carried out comparing herbicides for use on transplanted crops of spring cabbage. The seed was drilled on 15 July and planting out by machine took place on 21 August. Owing to the extremely dry conditions

at planting time the irrigation applied then was not wholly successful and considerable gapping up was necessary a week later. The weeds grew away rapidly after the irrigation and being past the stage at which chemical treatments would kill them had to be hoed off before the various herbicides could be applied.

In this trial simazine at 6 oz a.i. per acre gave a lower yield of greens in December than some other herbicides (9.2 tons per acre). A mixture of chlorpropham plus fenuron at 4 pints commercial material per acre gave the highest yield (11.1 tons per acre) but has to be worked into the soil pre-planting. Geigy A 1862 and noruron at 1.2 and 1.6 lb a.i. per acre also gave higher yields than did simazine. Noruron at 2.4 lb. a.i. per acre caused some crop damage. Weed control was very good with all treatments.

IRRIGATION AND SPACING OF SELF-BLANCHING CELERY

P. C. Rickard, *Arthur Rickwood Experimental Husbandry Farm*

This experiment is the first which has been laid out to test the expected interaction between planned irrigation regimes and close spacing of the crop. Earlier experiments have shown the advantage in yield of spacing at 10 in. square over 12 in. square, and most growers have now adopted this closer spacing. Similarly, the need for irrigation for close spaced celery is recognised, but whether this should be applied frequently at low soil moisture deficits (S.M.D.s) or infrequently when higher S.M.D.s have accumulated was not known.

The soil at the Arthur Rickwood E.H.F. is a peaty loam and at the site used each year for this experiment, the peat overlaid a fen clay subsoil. The peaty loam has in the region of 25–30 per cent organic matter content, and a water holding capacity of about 3 in. of available water in the top foot of soil.

S.M.D.s were derived using the Stanhill/Penman calculation, and averages adjusted for sunshine during 1968. During 1969 the British Standard Evaporation tank was used for the daily measurement of the evaporation from the open water surface and a monthly comparison of this with computerized Penman formula or averages adjusted for sunshine were remarkably close.

The self-blanching celery crops, variety Lathom Blanching, were planted in early June and irrigation was used on all plots to return the soil moisture to field capacity for plant establishment. The crop may take up to 10 or 12 weeks to reach full ground cover, and during the early stages of growth large soil moisture deficits will not build up despite periods of dry weather.

The treatments included restoring the soil moisture to field capacity during the growing period at 0.75 and at 1.50 S.M.D. No irrigation beyond that necessary for plant establishment was applied to the control plots. Within each irrigation regime were included spacings of 12 x 12, 12 x 9 and 12 x 6 in. and sample harvests were taken on three occasions, beginning when the earliest plots were in a marketable condition and spanning one month.

The S.M.D. did not exceed the lowest required deficit in 1968, and no irrigation was applied. Rainfall was such that for all practical purposes all treatments in the experiment were subjected to a frequent irrigation regime.

During 1969 dry weather during June and July accumulated a S.M.D. of 1.9 in. on the unirrigated plots and a further dry period during September and October brought the deficit up to 3.7 in. Over this period the infrequently irrigated treatment received a total of 3.8 in. of irrigation in 2 applications and the maximum S.M.D. reached was 2.1 in. The frequently irrigated plots received a total of 5.5 in. of irrigation in 7 applications and the maximum S.M.D. reached was 1.2 in.

The closest spacing (12 x 6 in.) produced the earliest, heaviest and best quality yields, but with either retarded harvesting or soil moisture stress deterioration was most rapid in this closely spaced plant. Conversely, the widest spacing (12 x 12 in.) continued to increase in yield over the period of harvesting, and was less sensitive to soil moisture stress; but this wide spacing did not produce a well blanched head until the later harvests, and in all cases petiole length was reduced (SEE PLATE VII LOWER).

As has been discussed above, the crop is very slow in achieving ground cover, and consequently large soil moisture deficits will not occur during dry weather in the early period of the crop. In 1969 S.M.D. differences between any of the treatments did not exceed 2 in. until 2 weeks before the first harvest, and there was little response to irrigation at this harvest. At the second and third harvests differences in S.M.D. were 2.3 and 0.9 inches between unirrigated and infrequent irrigation, and infrequent and frequent irrigation respectively; and at these harvests increasing the frequency of irrigation gave a good response in terms of yield, petiole length, blanching and succulent appearance of the marketable product.

PRODUCTION AND PROPAGATION OF VIRUS FREE STOCKS OF RHUBARB

M. W. Case, *Stockbridge House Experimental Horticulture Station*

Commercial rhubarb stocks in this country are almost completely infected with viruses of one kind or another. Those that have survived in commerce are for the most part virus tolerant varieties, the susceptible ones having succumbed to the disease and been discarded. Nevertheless, there is good reason to believe that the yield of even the tolerant varieties may be substantially increased if virus free clones can be established and maintained.

Virus free clones of established varieties have been raised by a technique of apical tip culture developed at the National Vegetable Research Station at Wellesbourne, Warwicks. This method initially produces virus free plants which to be of value must be propagated vegetatively to attain the size of commercial stocks. The traditional method of propagating rhubarb vegetatively is by division of the rootstock. At the speediest, roots are divided every two years to give a four- to six-fold increase and reestablishment of such roots after division can be very difficult in some seasons when weather

conditions are adverse. Clearly then if virus free clones are to be brought into commerce a more rapid method of vegetative propagation is necessary, for however patient we may be the slower the method of propagation the greater the danger of the stock becoming reinfected before it can be put into commercial use.

Work was undertaken at the University of Nottingham School of Agriculture to find a suitable rapid multiplication technique and this has been developed at Stockbridge House to multiply virus-free clones of three important commercial varieties Timperley Early, Prince Albert and Victoria. The multiplication takes place in a glasshouse which has been sealed as far as possible against entry of insects. This house is ventilated by thermostatically controlled fans which draw air into the house through Tygan screens. The fans maintain a slight positive pressure within the house which assists in excluding insects. The ends of the glasshouse are fitted with double doors giving entry and exit through lobbies within which are kept footbaths of a nematocide and smocks are worn to reduce the chances of insects being carried into the house on workers' clothing. Within the house virus sensitive indicator plants and young favoured host plants are grown with the rhubarb plants to draw attention to any viruliferous insects entering the house in spite of such precautions as are taken. Additionally, spraying and fumigation are carried out as a routine measure.

All stages of propagation are carried out in the house. The healthy parent plants are established in large pots or in sterilised border soil which has been isolated from unsterilized subsoil by sheets of polythene. The propagation is by leaf bud cuttings which consist of a leaf with its petiole and small axillary bud and about a millimetre of parent plant tissue. These cuttings are rooted under a mist propagator with great success from early March to mid September but with difficulty during the shorter winter days. The young plants are potted in sterilized soil and grown on until they have formed about five leaves at which stage they have formed a small root crown which can be divided or used to form further leaf bud cuttings as seems most suitable. Using these methods three generations of plants may be raised in one growing season giving a multiplication rate of upwards of 100 plants from one parent plant annually. Attempts have been made to overcome the adverse effects of the short winter days on this propagation technique but neither extension of the daylength nor improvement of the quality of the winter light by the use of mercury vapour lamps have been successful in achieving this end. During the winter months cuttings root more slowly and the delay results in infection by bacteria which cause rotting, and work is in progress on the control of this trouble.

Work has also started at Stockbridge House to assess the rate of reinfestation of virus-free stocks of rhubarb in the field both in a commercial situation and under conditions where reasonable precautions are taken to reduce the exposure of such stocks to insect and nematode vectors of viruses which affect this crop.

DIRECT DRILLED WINTER CAULIFLOWER

B. H. Houghton, *Rosewarne Experimental Horticulture Station*

The thoughts which prompted us to undertake work on direct drilling of winter cauliflower or Roscoff broccoli, although primarily intended to reduce production costs are directed towards this aim in a rather different way from the use of this method in cabbage production.

Due to the long period over which many broccoli varieties mature, the cost of cutting the crop can be very high indeed. There is often much walking to do to find only a small number of heads, particularly at the beginning and end of a crop or at other times when cold weather slows the rate of growth. If by means of direct seeding the crop would as a result grow and develop at a uniform rate, then heading at a similar period might be expected. With the summer cauliflower crop this has been found to be the case, but in the first season of trials with broccoli there was no swing to a shorter cut for the 3 varieties used, neither did any of the 3 sowing dates used make a difference in this respect. Early results from a second trial also showed that with one variety, Saint Gwithian (Extra Early), this system offers no advantages.

As with cabbage, the usual method employed for controlling club root infection (dipping the plants in calomel at transplanting time) becomes impossible in direct drilled crops, and cabbage root fly control is not as easy as dipping the plant in an insecticide.

Weed control in the direct drilled crop with normal rates of propachlor was satisfactory for 5 weeks, but thereafter it was essential to cultivate. As with transplanted broccoli, simazine at 6 oz a.i. per acre gave very good weed control if put on when the plants are about 12 in. tall, but cool and wet weather for several days after application is necessary for maximum weed suppression.

Experimental Husbandry Farms and Horticultural Stations

<i>Centre</i>	<i>Acreage</i>	<i>Main Farming and Experimental Activities</i>
Arthur Rickwood E.H.F. Mepal, Ely, Cambs.	150	Arable farm on peat soils of varying depth. Studies on peat wastage. Cash crops, including potatoes, sugar beet, vegetables and cereals.
Boxworth E.H.F. Boxworth, Cambs. CB3 8NN	858	Cereal and dairy farm on boulder clay. Intensive cereal cropping, manuring, weed control. Break crops including beans. Feeding and management of Friesians for milk and beef.
Bridget's E.H.F. Martyr Worthy, Winchester, Hants.	1,035	Mixed farm on chalk. Cereals: intensive cropping and manuring. Break crops. Leys: fodder conservation and herbage seed production. Large Friesian herd; management and feeding studies. Intensive management of sheep.
Drayton E.H.F. Alcester Road, Stratford-on-Avon Warwickshire.	450	Mixed farm on Lias clay. Cereals: intensive cropping; winter beans. Fodder conservation. Beef cattle: grazing, feeding and calf-rearing. Cross-bred sheep: winter housing of ewes, intensification on pasture.
Gleadthorpe E.H.F. Welbeck Colliery Village, Mansfield, Notts.	493	Light sand arable farm. Cereals: intensive cropping, manuring. Potatoes, sugar beet, carrots and other cash crops. Irrigation. Feeding and grazing of Friesian beef cattle. Poultry: feeding and management.
Great House E.H.F. Helmshore, Rossendale, Lancs. BB4 4AJ	460	High-lying Pennine farm in industrial area. Grassland production and utilization. Feeding and management of Friesian cattle, Gritstone Sheep and Large White Pigs.
High Mowthorpe E.H.F. Duggleby, Malton, Yorks.	1,080	Mixed farm on high-lying chalk. Cereals and seed potato growing. Leys: grazing and fodder conservation. Single suckled and artificially reared beef cattle. Cross-bred sheep.

<i>Centre</i>	<i>Acreage</i>	<i>Main Farming and Experimental Activities</i>
Liscombe E.H.F. Dulverton, Somerset.	495	Upland grass farm adjoining Exmoor. Manuring and management of grass, fodder conservation. Rearing and feeding single-suckled and artificially reared cross-bred cattle. Intensive sheep grazing.
Pwllpeiran E.H.F. Cwmystwyth, Aberystwyth, Cards.	3,100	Mountain farm. Welsh Black and cross-bred suckler cattle. Welsh Mountain sheep: methods of wintering, feeding, flock management and cross-breeding.
Redesdale E.H.F. Rochester, Otterburn, Newcastle-upon-Tyne.	3,832	Pennine hill farm. Blackface sheep, Galloway and Cross suckler cows. Management of stock: more intensive stocking and provision of fodder.
Rosemaund E.H.F. Preston Wynne, Hereford.	435	Mixed farm on heavy red sandstone soil. Cereals, cider apples and hops. Grazing and feeding cross-bred beef cattle and sheep. N.I.A.B. Regional Trial Centre.
Terrington E.H.F. Terrington St. Clement, King's Lynn, Norfolk.	200	Silt land arable farm. All aspects of potato production. Also sugar beet, beans, peas and cereals. Large White pigs. N.I.A.B. Regional Trial Centre.
Trawscoed E.H.F. Trawscoed, Aberystwyth, Cards.	808	A mixed farm on shale soils with moor. Rearing, feeding and management of Friesian dairy cattle and cross-bred suckler beef cattle. Welsh and Halfbred sheep and Large White Pigs. N.I.A.B. Regional Trial Centre.
Cleppa Park E.H.S. Newport, Monmouthshire, NP1 9YT.	68	Production of soft fruit, vegetable and flower crops under local conditions in the open, and under glass.
Efford E.H.S. Lymington, Hampshire, SO4 0LZ.	376	Trials with top and soft fruit; vegetables including early potatoes; glasshouse crops including tomatoes, lettuce; flower crops; irrigation.
Fairfield E.H.S. Greenhalgh, Kirkham, Preston, Lancs. PR4 3HH.	22	Glasshouse crops including tomatoes, lettuce; flowers; mushrooms.

<i>Centre</i>	<i>Acreage</i>	<i>Main Farming and Experimental Activities</i>
Kirton E.H.S. Kirton, Boston, Lincolnshire.	104	Bulb flower crops including hot water treatment, storage and forcing; strawberries; vegetables, especially summer cauliflower.
Lee Valley E.H.S. Ware Road, Hoddesdon, Herts.	26	Glasshouse crops including tomatoes, cucumbers, lettuce, chrysanthemums; flowers and some intensive vegetables in the open; mushrooms.
Luddington E.H.S. Stratford-on-Avon Warwickshire.	230	Apples, plums and soft fruit, pest and disease control, nutrition and root-stocks; vegetables; flowers; glasshouse crops; irrigation; weed control.
Rosewarne E.H.S. Camborne, Cornwall.	115	Bulb and other flower crops; vegetables, including early potatoes; mobile glass-houses; shelter; weed control.
Ellbridge Sub-Station, Hatt, Saltash, Cornwall.	5	The study of crops produced in the Tamar Valley.
Isles of Scilly Demonstration Station, Trenoweth, St. Mary's, Isles of Scilly.	3	Bulb crops.
Stockbridge House E.H.S., Cawood, Selby Yorks.	161	Vegetable crops including rhubarb; soft fruit; crops and rotations for fixed and mobile structures; shelter; mushrooms; flowers.
National Fruit Trials Brogdale Farm, Faversham, Kent.	185	Testing and classification of all types of top and soft fruit.
Norfolk Agricultural Stn, Morley St. Botolph, Wymondham, Norfolk.	434	This independent body collaborates with the Experimental Husbandry Farms in conducting various experiments. Medium loam soils. Intensive cereals, sugar beet, peas and potatoes. Feeding of cross-bred beef cattle.

N.A.A.S. EXPERIMENTAL FARMS & STATIONS

● Husbandry Farm ▲ Horticulture Station
 △ Horticulture Sub-Station ▲ N.A.A.S. Horticultural Demonstration Station



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